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NATURAL HAZARDS TRAINING MANUAL

PROVINCIAL POLICY STATEMENT

PUBLIC HEALTH AND SAFETY
POLICIES 3.1

- ***Great Lakes - St. Lawrence River System***
- ***Large Inland Lakes***
- ***River and Stream Systems***
- ***Hazardous Sites***

Version 1.0

Ontario Ministry of Natural Resources
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1.0 INTRODUCTION

Increasing pressure to live in close proximity to water, particularly over the last forty years, has resulted in extensive and increasing property damage, risks to public health and safety, detrimental impacts to local ecosystems, and immeasurable social disruption costs. For municipalities and governments, it has also meant increasing public liability, escalating public costs related to the installation, maintenance, replacement or upgrade of protection works required to safeguard vulnerable developments, and mounting public costs to address unwise individual decisions.

Describing flooding, erosion, dynamic beaches, unstable soils and unstable bedrock, as a "problem" or "natural hazards" is actually misleading. They are essentially naturally occurring physical and ecological processes that for thousands of years have continuously shaped and re-shaped the landscape. These processes are only perceived to be a problem or a "hazard" when people and structures are located within the area(s) directly impacted by these natural processes.

Human responses to natural hazards have historically focussed on the construction of various forms of protection or remedial control works. The premise being that all "problems" resulting from natural physical processes (e.g., erosion, flooding) can be resolved through the use of structural solutions. Unfortunately, in a significant number of cases, the protection works were installed in an ad hoc fashion and more often than not, they largely ignored natural processes and environmental impacts. In addition, the failure or improper selection, design or installation of protection works, often resulted in adverse environmental impacts and aggravated or created new hazards, rather than protecting against flood or erosion damages as initially intended. As a result, there have been marked increases in property damages, losses of land, social disruption and environmental degradation.

In accordance with the overall purpose and intent of the *Provincial Policy Statement* (Policy 3.1), *development* and *site alterations* should be located in areas which are not subject to natural hazards. Flexibility to recognize unique, local situations, however, is provided where the natural hazards are considered to be minor in nature such that certain types of *development* and *site alteration* can safely be permitted. In those unique, local situations where the natural hazards are considered to be minor in nature and can be addressed in an environmentally sound manner, *development* and *site alterations* may be permitted.

To assist in determining how natural hazards should be addressed, three key documents have been developed:

- *Provincial Policy Statement*;
- *Interpretation Handbook*; and
- *Natural Hazards Training Manual*.

The *Natural Hazards Training Manual* complements and should be read in conjunction with the first two documents. To ensure that other policy interests are not compromised, where appropriate, the Training Manuals addressing other resource interests of provincial interest should also be consulted (e.g., *Natural Heritage)*.

The purpose of the *Natural Hazards Training Manual* is to:

- overview the suggested approaches and standards for defining the areas of provincial interest related to natural hazards (Policy 3.1.1);
- identify flexibility that could be applied to address unique, local situations;
- identify situations where *development* and *site alterations* should not to be permitted (Policy 3.1.2);
- identify approaches that could be applied where *development* and *site alterations* may be considered (Policy 3.1.3); and

- provide information on the linkages between each of the natural hazard policies and other resource policy interests and how they may be addressed.

The approaches outlined in this Training Manual reflect current engineering, geotechnical and scientific practices and principles that have been developed, tested and accepted within Ontario and internationally. For ease of use, the approaches have been structured in such a way that they can be applied directly to an area impacted by natural hazards, such as a shoreline, river or stream, without the need for additional studies.

Although the approaches outlined in this Training Manual may preclude the need for studies, the Manual also identifies those areas where the flexibility to adjust these approaches to reflect unique, local situations may be appropriate. The flexibility to determine a local solution, based on accepted engineering, geotechnical and/or scientific practices and principles, enables the local municipality or planning board to recognize local conditions while at the same time fulfilling the overall intent and purpose of the natural hazards policies. For example, although the Manual outlines a suggested approach for defining *erosion hazard* limits along the shorelines of *large inland lakes*, the suggested approach may be considered excessive in areas containing highly stable bedrock formations. Where these situations exist, the Manual identifies how flexibility may be applied in the determination of a reduced *erosion hazard* approach that reflects the more stable nature of their shoreline while at the same time adhering to the provincial policy interest of minimizing risks to life and property. However, in those areas where the shoreline bedrock is "soft", unstable and subject to the natural processes of erosion, the approach used for defining *erosion hazard* limits, as outlined in this Training Manual, should continue to be applied.

Similarly, flexibility also exists for the local municipality or planning agency to consider an increased *erosion hazard* limit where appropriate. For instance, in areas of highly erodible and unstable soils, the suggested approach may not be sufficient enough to safeguard the health and safety of local residents. In these situations, the local municipality or planning board also has the flexibility to increase the *erosion hazard* limit to reflect the local situation.

Where more detailed technical information or explanation is required beyond that contained in the *Natural Hazards Training Manual*, the Ministry of Natural Resources' series of supporting Technical Guides should be consulted including:

- *Technical Guide for Great Lakes - St. Lawrence River Shorelines*
- *Technical Guide for Large Inland Lakes Shorelines*
- *Technical Guide for River and Stream Systems*
- *Technical Guide for Hazardous Sites*

In essence, the *Natural Hazards Training Manual* is a brief synopsis of the detailed engineering, geotechnical and scientific practices and principles outlined in each of these individual Technical Guides.

2.0 POLICY OVERVIEW

The *Provincial Policy Statement* is based on three guiding principles:

> ***Ontario's long-term economic prosperity, environmental health and social well-being depend on:***
>
> 1. ***managing change and promoting efficient, cost-effective development and land use patterns which stimulate economic growth and protect the environment and public health;***
> 2. ***protecting resources for their economic use and/or environmental benefits; and***
> 3. ***reducing the potential for public cost or risk to Ontario's residents by directing development away from areas where there is a risk to public health or safety or property damage.***

In addition, Policy 1.1.1 states that to develop strong communities as part of efficient, cost-effective development and land use patterns:

> ***(f) Development and land use patterns which cause environmental or public health and safety concerns will be avoided.***

Development located within *hazardous lands* and *hazardous sites* places the health and safety of area residents and their properties at risk. This has been clearly and repeatedly demonstrated across the province by the losses of life, mounting property damages and increasing land losses where developments have been located within hazardous areas.

In other words, it is more cost effective to avoid the hazards upfront and early in the planning process than it is to deal with the long-term, and often escalating costs of developing within *hazardous lands* and *hazardous sites* (e.g., property damages, installing and maintaining protection works, developing and implementing emergency preparedness plans and emergency evacuation plans).

For this reason, the primary premise of *Policy 3.1: Public Health and Safety* for *Natural Hazards* is that development should be directed to locations outside of *hazardous lands* and *hazardous sites* to minimize the risks and costs posed by natural hazards (i.e., flooding, erosion, dynamic beaches, unstable soils, and unstable bedrock).

In keeping with this overall intent, the policies governing *Public Health and Safety* have been structured in the following manner:

- Policy 3.1.1 defines the "areas of provincial interest" (i.e., *hazardous lands* and *hazardous sites)* and identifies which type of natural hazards are of concern within each of these areas;
- Policy 3.1.2 identifies that there are certain portions of the "areas of provincial interest" (i.e., Policy 3.1.1), where the risks and threats to life and property are considered to be unacceptable, and as such, *development* and *site alteration* should not be permitted; and
- Policy 3.1.3 identifies the matters to be addressed should *development* and *site alteration* be considered within the "areas of provincial interest" (excluding those portions as identified in Policy 3.1.2).

The "areas of provincial interest" outlined in Policy 3.1.1 include:

- ***hazardous lands*** **adjacent to the shorelines of the** ***Great Lakes - St. Lawrence River System*** **and** ***large inland lakes*** **which are impacted by** ***flooding, erosion*** **and/or** ***dynamic beach hazards;***

- ***hazardous lands*** **adjacent to** ***river and stream systems*** **which are impacted by** ***flooding*** **and/or** ***erosion hazards;*** **and**

- ***hazardous sites*** including those lands involving unstable soils (e.g., sensitive marine clays, organic soils) and unstable bedrock (e.g., karst formations).

The approaches to be used to define each type of *hazardous lands* and *hazardous sites* are summarized in Table 1 and discussed in greater detail in Section 4.1.1 of this Training Manual. In addition, Section 4.1.1 provides technical direction on the flexibility to adjust these approaches to reflect unique, local situations.

Policy 3.1.2 then introduces that there are certain portions of these "areas of provincial interest" where the risks to life and property are unacceptable and as such, *development* and *site alterations* should not be permitted including:

- ***defined portions of the dynamic beach*** (Policy 3.1.2 (a))
  - applies only to shorelines of the *Great Lakes - St. Lawrence River System* and *large inland lakes* where a *dynamic beach* has been identified

- ***defined portions of the one hundred year flood level*** **along connecting channels** (Policy 3.1.2 (b))
  - applies only to the connecting channels of the *Great Lakes - St. Lawrence River System*

- **a** ***floodway*** **(except in those exceptional situations where a Special Policy Area has been approved)** (Policy 3.1.2 (c))
  - applies only to *river and stream systems*

Section 4.2.1 of this Training Manual provides a more detailed discussion of the provincial rationale for suggesting that *development* and *site alteration* within each of these areas would be inappropriate and the technical matters to be addressed when defining these areas.

Finally, Policy 3.1.3 explains the matters that should all be fulfilled where *development* and *site alteration* are being considered within these "areas of provincial interest". In specific, Policy 3.1.3 states that:

- **Except as provided in policy 3.1.2,** ***development*** **and** ***site alteration*** **may be permitted in** ***hazardous lands*** **and** ***hazardous sites*****, provided that all of the following can be achieved:**

  a) the hazards can be safely addressed, and the ***development*** **and** ***site alteration*** **is carried out in accordance with** ***established standards and procedures;***
  b) new hazards are not created and existing hazards are not aggravated;
  c) no adverse environmental impacts will result;
  d) vehicles and people have a way of safely entering and exiting the area during times of flooding, erosion and other emergencies; and
  e) the development does not include ***institutional uses*** **or** ***essential emergency services*** **or the disposal, manufacture, treatment or storage of** ***hazardous substances.***

Table 1: Policy Approaches for Natural Hazards

Area of Provincial Interest	Defining Policy Approaches **
Hazardous Lands: ***. Great Lakes - St. Lawrence River System*** ***. large inland lakes***	Area of provincial interest based on the furthest landward limit of: . ***flooding hazards*** involving the combined influence of: . **lake levels** -- *100 year flood level**; PLUS . **flood allowance involving the combined influence of wave uprush and other water related hazards** -- 15 metres* (Great Lakes), or 5 metres* (connecting channels, *large inland lakes)* . ***dynamic beach hazards*** involving the combined influence of: . **flooding** -- *involving 100 year flood level** plus 15 metres* (Great Lakes), or *100 year flood level** plus 5 metres* (connecting channels, *large inland lakes);* PLUS . **dynamic beach allowance** -- 30 metres* (Great Lakes), or 10 metres* *(large inland lakes),* . ***erosion hazards*** involving the combined influence of (two step process): . Step 1: select one of : . **stable slope** (3:1 slope*) ; PLUS **recession rate allowance** (100 times the average annual recession rate where a minimum of 35 years of reliable recession rate information is used); OR . **stable slope** (3:1 slope*); PLUS **erosion allowance** (30 metres* (Great Lakes) or 15 metres* (*large inland lakes*) where there is insufficient recession rate information); . Step 2: **whichever is the greater of:** . Step 1 selection OR . **erosion allowance** (30 metres* (Great Lakes) or 15 metres* (*large inland lakes*) measured from the first lakeward break in slope
Hazardous Lands: ***. river and stream systems***	Area of provincial interest based on the furthest landward limit of: . ***flooding hazards*** -- greater of (note: **minimum standard is *100 year flood event*)**: . *storm centred event* (e.g., Hurricane Hazel, Timmins), OR . *100 year flood*, OR . *observed flood event.* . ***erosion hazards:*** . **confined systems** and **terrain-dependent systems** (consisting of cohesive materials) involving the combined influence of: . **toe erosion allowance** (15 metres* (depending on soil conditions) or 100 times the average annual recession rate where a minimum of 25 years of reliable data is used), PLUS . a **stable slope allowance** (3:1* h:v), PLUS . an **erosion access allowance** (6 metres*) . **unconfined systems** and **terrain-dependent systems** (consisting of cohesionless materials) involving the combined influence of: . the *flooding hazard* limit or **meander belt allowance**, PLUS . an **erosion access allowance** (6 metres*)
Hazardous Sites ***. unstable soils*** ***. unstable bedrock***	Area of provincial interest based on studies using accepted geotechnical and engineering principles and practices addressing: . toe erosion, slope stability, soil structure, bedrock material

Note: * flexibility exists to recognize local conditions by undertaking studies using accepted engineering, geotechnical and/or scientific studies

** see the supporting MNR Technical Guides for more detailed information and implementation approaches

Ensuring that the ***hazards can be safely addressed*** (Policy 3.1.3 (a)) essentially means that any measure or action intended to minimize or reduce the hazards should not place the safety of people or property and developments at risk. For example, in flood susceptible shoreline areas, elevating a building onto piles may be considered an appropriate action to address the *flooding hazard*. However, addressing the hazards when dealing with shoreline environments also requires that any existing or potential hazards associated with *erosion* and/or *dynamic beach hazards* must also be addressed. Following on with the above example of building in a flood susceptible shoreline, if the proposed building to be floodproofed is located on an eroding and unstable shoreline, and the piles are improperly designed and installed, the structural soundness of the building may be jeopardized and those living in the structure placed at risk. The result being that the hazard has not been *safely addressed*.

More detailed direction and information on "addressing the hazards" is provided in Sections 4.2.2, 4.2.3, 4.2.4 and 4.2.5 of this Training Manual.

Ensuring that the ***development and site alteration is carried out in accordance with established standards and procedures*** (Policy 3.1.3 (a)) confirms that where *development* and *site alteration* are considered they should be evaluated and implemented in a manner consistent with current, widely-accepted principles and practices (e.g., engineering, geomorphology, botany and zoology). By definition, *established standards and procedures* includes actions related to *floodproofing, protection works* and *access* that are intended to *address the hazards*.

Floodproofing basically involves a combination of measures or changes into the basic design and/or construction of buildings, structures or properties that have the effect of reducing or eliminating flood hazards (e.g., lake levels, wave uprush and other water related hazards in shoreline areas).

Similarly, *protection works* involve the combination of non-structural or structural works, an allowance for slope stability, and a hazard allowance for the flooding and erosion hazards that have the effect of reducing or minimizing *flooding*, *erosion* and/or *dynamic beach hazards*. Where protection works are considered, access by heavy machinery to repair and maintain the protection works should also be provided.

Lastly, *access* involves ensuring that safe pedestrian and vehicular movement is provided and that the design of the development is such that access by heavy machinery to the protection works, for repair and replacement, should they fail, is not impeded. For example, buildings sited too close to one another, thereby preventing the access of heavy machinery to repair or replace a failed protection works during an emergency, may place additional lands and people at risk.

More detailed information and direction on the definition and use of each of these *established standards and procedures* is provided in Section 4.2.3 of this Training Manual.

Ensuring that ***new hazards are not created and existing hazards are not aggravated*** (Policy 3.1.3(b)) essentially means that any actions taken to address the hazards should not result in new hazards being formed or existing hazards being exacerbated. For example, the installation of toe protection works at the base of an eroding river bank may be an appropriate means of addressing the erosion hazard. However, if the protection works are improperly designed, installed or maintained they may deflect the erosive forces of water flowing within the river channel to adjacent lands causing the unacceptable formation of new erosion hazards or an unacceptable acceleration of existing erosion problems.

More detailed information and direction on determining when, where and to what degree new hazards may be created and existing hazards may be aggravated is provided through MNR's suggested approach for balancing development interests and natural hazards (i.e., physical and biological processes) outlined in Section 4.2.5 of this Training Manual. An example of how this "suggested approach" may be applied is provided in the appendix supporting this Training Manual (i.e., Appendix 1.0 for shorelines of the *Great Lakes - St. Lawrence River Systems)*.

Ensuring that ***no adverse environmental effects will result*** (Policy 3.1.3 (c)) essentially means that where *development* and *site alteration* are being proposed the function and integrity of the local environment or ecosystem, including plant and animal life, should not to be adversely affected as a result of the *development* and/or *site alteration*. It is recognized that any and all forms of *development* and *site alteration* pose some degree of environmental impact. The key in fulfilling this requirement is ensuring that any and all environmental impacts are minimized. For example, where shoreline protection works are intended to address an erosion hazard, an alteration in the timing, design, or method of installation may minimize potential environmental impacts such that the development poses no adverse environmental effects to the function or integrity of the shoreline ecosystem. Where the function and integrity of the shoreline ecosystem, and as such, the environment are adversely affected, the *development* and *site alteration* should not be permitted. Care should also be taken to ensure that protection works designed to minimize environmental impacts do not in turn result in the creation of new hazards or the aggravation of existing physical hazards. Where this latter situation arises, the *development* and *site alteration* should also not be permitted.

Additional information on how to determine whether adverse environmental effects will or will not result is provided through the use of MNR's suggested approach for balancing development interests and natural hazards, including physical and biological processes, outlined in Section 4.2.5 and applied in Appendix 1.0.

Ensuring that ***vehicles and people have a way of safely entering and exiting the area during times of flooding, erosion and other emergencies*** (Policy 3.1.3 (d)) essentially means that in the planning and design of the development the evacuation of people, either on foot or in vehicles, has been accommodated (e.g., elevating access roads above the defined flood standards, the preparation of municipal emergency preparedness and action plans). Care should be taken when fulfilling this requirement to ensure that the selected approach does not compromise the other requirements identified in Policy 3.1.3. For example, constructing an elevated access roadway to permit development within a flood susceptible area that in turn increases flooding on adjacent lands and compromises Policy 3.1.3 (b) should not be considered acceptable.

More detailed information and direction on providing safe access is provided in Section 4.2.3 of this Training Manual.

Ensuring that the ***development does not include institutional uses*** or ***essential emergency services or the disposal, manufacture, treatment or storage of hazardous substances*** (Policy 3.1.3 (e)) is essentially intended to prevent development that poses an unacceptable risk to public health and safety from locating within hazardous areas. For instance, *institutional uses*, involving facilities such as hospitals, nursing homes, school nurseries, day care and schools, are considered unacceptable uses in hazardous areas due to the threat to the safe evacuation of the sick, elderly, physically challenged or young during an emergency. *Essential emergency services* involving services such as fire, police and ambulance stations and electrical substations which may be impaired or rendered inoperable during an emergency are also considered unacceptable uses in hazardous areas. Finally, the disposal, manufacture, treatment or storage of *hazardous substances*, involving a wide range of materials that are toxic, ignitable, corrosive, reactive, radioactive or pathological, are considered unacceptable uses as they pose a danger to public health, safety and the environment.

Where these requirements cannot be fulfilled (i.e., Policy 3.1.3 (a) to (e) inclusive), the intent of Policy 3.1.3 is that the proposed *development* and *site alteration* should be directed to a location outside of the defined *hazardous lands* and/or *hazardous sites*.

Alternatively, where these requirements can be fulfilled (i.e., Policy 3.1.3 (a) to (e) inclusive), the Policy provides the flexibility for *development* and *site alteration* to be considered within the least hazardous portions of the *hazardous lands* and/or *hazardous sites*.

When applying this flexibility, care should be taken to ensure that the risk(s) are clearly understood, that the potential or feasibility for development to safely locate within the least hazardous portions of these areas is justifiable, and that the approach(es) to be used to permit *development* and *site alteration* within the least hazardous portions of these areas are sound, reasonable and can be implemented.

Lastly, care should also be taken to ensure that the interests and intent of other policies addressing the same areas are not compromised (e.g., fish habitat, wetlands, water quality and quantity, etc. which may not consider development within these areas to be appropriate or acceptable).

3.0 GENERAL APPROACHES: LINKAGES TO ECOSYSTEM-BASED PLANNING

The *Provincial Policy Statement* outlines the provincial interest in protecting public health and safety, and provides direction on how this is to be achieved by stating that:

> ***A coordinated approach should be achieved when dealing with issues which cross municipal boundaries, including:***
> ***2. ecosystem and watershed related issues; and***
> ***3. shoreline and riverine hazards.*** (Policy 1.1.1 (e))
>
> ***Development and land use patterns which may cause environmental or public health and safety concerns will be avoided.*** (Policy 1.1.1 (f)).

Municipalities and planning boards are increasingly finding that effective planning of their communities requires that they look to and balance a wide range of public and private interests that may extend well beyond a single development site. Ecosystem-based planning, involving an upfront evaluation of numerous, and often competing, land use and natural resource interests over large tracts of land provides a viable means of examining and developing site specific planning strategies that balance local, as well as community-based needs.

Municipalities and planning boards are also recognizing that early and full integration of natural hazards management into the overall planning approach results in planning and development strategies that promote the development of economically viable communities while still maintaining and enhancing the integrity of the ecosystem, protecting human life and minimizing property losses and social disruption.

Two examples of ecosystem-based planning, or comprehensive approaches to planning and management, include shoreline management planning and watershed management planning. Both approaches involve the early and full integration and management of a wide range of environmental, economic, cultural and social interests within a defined planning unit (e.g., comprehensive stretch of shoreline, watershed and/or subwatershed).

Guidance on the development and implementation of these planning approaches is provided through various intergovernmental (i.e., provincial/federal) and interministerial documents including but not limited to:

- *Water Management on a Watershed Basis: Implementing An Ecosystem Approach,* June 1993;
- *Subwatershed Planning,* June 1993;
- *Integrating Water Management Objectives into Municipal Planning Documents*, June 1993.
- *Shoreline Management: Implementing an Ecosystem Approach*, 1997 (in preparation); and
- *Great Lakes Shore Management Plan Guide,* Department of Fisheries and Oceans Canada, Environment Canada, and the Ontario Ministry of Natural Resources, October 1981.

4.0 POLICY SPECIFICS

Section 2.0 of this Training Manual provided a brief overview of the structure and overall intent of the policies governing natural hazards. The purpose of Section 4.0 is to provide a more specific and detailed explanation of the technical aspects of the policies, approaches and standards governing natural hazards including:

- suggested approaches for defining the "areas of provincial interest" (Section 4.1):
  - *Great Lakes - St. Lawrence River System* and *large inland lakes* (Section 4.1.1);
  - *river and stream systems* (Section 4.1.2);
  - *hazardous sites* (Section 4.1.3); and
  - linkages between the natural hazards (Section 4.1.4).

- suggested approaches where *development* and *site alteration* within *hazardous lands* and *hazardous sites* may be considered (Section 4.2):
  - suggested approaches for defining those portions of the "areas of provincial interest" where *development* and *site alteration* should not permitted (Section 4.2.1);
  - *established standards and procedures* which should be applied (Section 4.2.3);
  - additional considerations when dealing with *hazardous sites* (Section 4.2.4); and
  - overview of a suggested approach for balancing development interests and the physical and biological processes associated with natural hazards (Section 4.2.5).

4.1 Defining the Areas of Provincial Interest (Policies 3.1.1)

4.1.1 *Hazardous Lands*: *Great Lakes - St. Lawrence River System* and *Large Inland Lakes* (Policy 3.1.1(a))

By definition, the *Great Lakes - St. Lawrence River System* includes the major water system consisting of Lakes Superior, Huron, St. Clair Erie and Ontario and their connecting channels, the St. Mary's, St. Clair, Detroit, Niagara and St. Lawrence Rivers, within the boundaries of the Province of Ontario. Similarly, *large inland lakes* includes those waterbodies having a surface area of equal to or greater than 100 square kilometres where there is no measurable or predictable response to a single runoff event.

Shoreline flooding, erosion and dynamic beach processes are physical hazards, highly influenced by local conditions. As such, a planning or management approach successfully applied in one area may be totally unacceptable or inappropriate in another. The key to selecting the most appropriate planning or management approach(es) is to ensure that they have been developed with due consideration to local conditions and that they reflect the overall intent of the Policy.

In determining and defining shoreline *flooding, erosion* and *dynamic beach hazards*, one should first have an understanding of the physical processes that continuously shape and re-shape these shorelines. These processes include, but are not limited to:

- shore regression, transgression or stability;
- wave shoaling, refraction and diffraction;
- breaking waves;
- nearshore currents;
- erosion by waves;
- sediment transport (e.g., sources, sinks, littoral cells, sediment budgets, etc.);
- wind and wave climates;

- wind or aeolian forces and action;
- water level fluctuations;
- ground water and surface water flows;
- ice;
- weathering; and
- human activities.

When studying and determining an overall shoreline planning and management approach, one should first establish a method for describing and comparing shorelines having similar physical characteristics and shoreline processes. The objective of any shoreline classification scheme is to provide a consistent, technically sound and viable approach for dividing a given stretch of shoreline into manageable units.

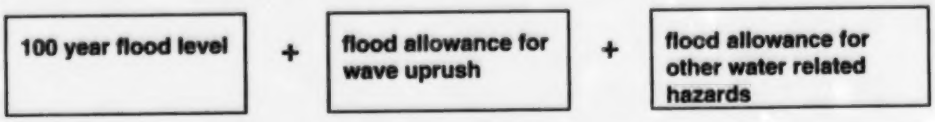
The Ministry of Natural Resources (MNR) has developed a "*recommended shoreline classification scheme*" to identify unique or similar segments of shoreline (i.e., based on shore type). Once applied, use of this "classification scheme" then makes it much easier to consistently determine the factors and processes that influence the severity of the *flooding, erosion* and *dynamic beach hazards* and to select the management approach(es) best suited for that particular stretch of shoreline (for more detailed information see the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996)).

The "area of provincial interest", or *hazardous lands* for the *Great Lakes - St. Lawrence River System* and *large inland lakes* (Figure 1), is based on the delineation of the furthest landward limit of the three key shoreline natural hazards:

- ***flooding hazards***
- ***erosion hazards***
- ***dynamic beach hazards.***

a) *Flooding Hazards*

By definition, three individual components should be used to define areas *flooding hazards* along the *Great Lakes - St. Lawrence River System* and *large inland lakes* shorelines (Figure 2) including:

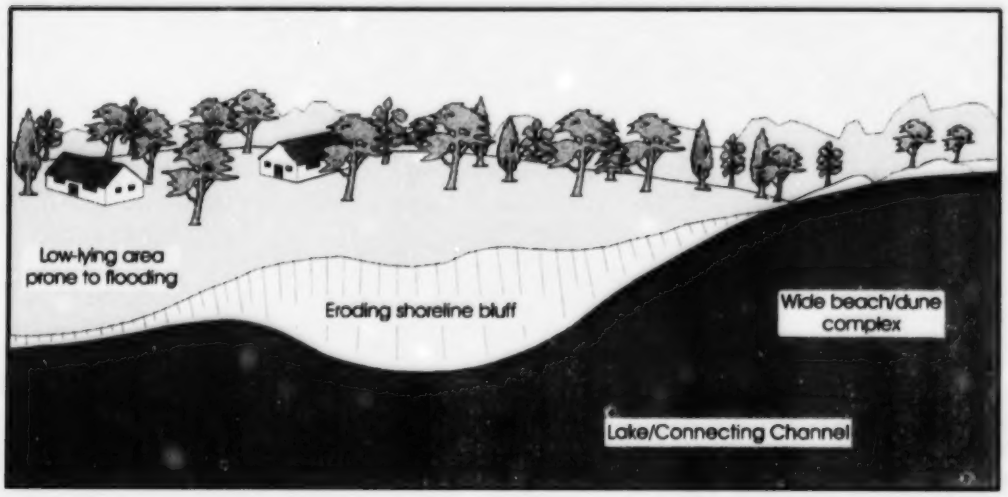


i) 100 Year Flood Level

For shorelines adjacent to the Great Lakes (i.e., Superior, Huron, St. Clair, Erie and Ontario), the 100 year flood level is defined as the peak instantaneous stillwater level (i.e., a combination of mean monthly water levels and wind setups), having a total probability of being equalled or exceeded during any year of 1%. This means that on average, during a 100 year period, the 100 year flood level is expected to be equalled or exceeded once.

Figure 1: ***Hazardous Lands: Great Lakes - St. Lawrence River System* and *Large Inland Lakes***

a) 3-D View of the Shoreline



b) Topographic View of the Shoreline

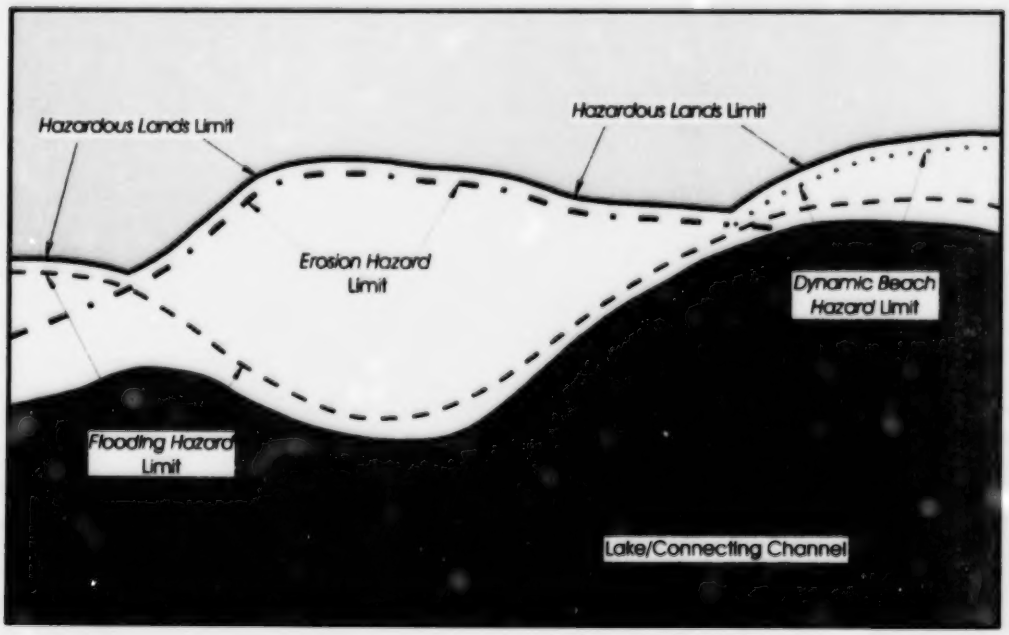
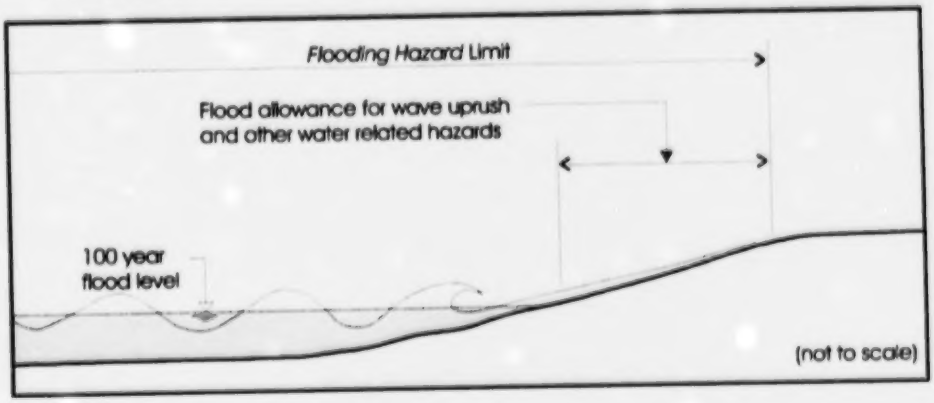


Figure 2: *Flooding Hazard* Limit: *Great Lakes - St. Lawrence River System* and *Large Inland Lakes*


Flooding Hazard Limit
Flood allowance for wave uprush and other water related hazards
100 year flood level
(not to scale)

For each of the Great Lakes there are many separate combinations of monthly mean levels and wind setups which could result in the same local water level. For instance, a low monthly mean level combined with a high wind setup could result in the same flooding impact as a high monthly mean level and a low wind setup. Therefore, 100 year flood levels for the shorelines along each of the Great Lakes have been determined by calculating the probability of all possible combinations of the entire range of monthly mean lake levels and wind setups which could combine to result in a peak instantaneous water level having a total probability of being equalled or exceeded of 1% in any given year.

Calculation of 100 year flood levels (i.e., monthly mean, wind setup) for the Great Lakes are based on a number of key factors:

- frequency distribution of highest annual monthly mean lake levels;
- surge or wind setup from recorded surge gauges;
- average wind speed data (duration, direction, speed);
- calibration/use of SURGE model; and
- serial/autocorrelation analysis.

For the connecting channels of the *Great Lakes - St. Lawrence River System* (e.g., St. Mary's, St. Clair, Detroit, Niagara, and St. Lawrence Rivers), the 100 year flood level, defined as the peak instantaneous stillwater level having a 1% probability or chance of being equalled or exceeded in any year, is based on a frequency analysis of recorded, historical data adjusted to "Basis of Comparison" conditions (e.g., impacts of regulation on inflows/outflows).

For *large inland lakes*, the 100 year flood level, is defined as the combination of lake levels and wind setups that have a 1% probability or chance of being equalled or exceeded in any given year. Where sufficient water level records do not exist, the 100 year flood level should be based on the highest known water level and wind setup.

Calculation of the 100 year flood levels at various locations throughout the *Great Lakes - St. Lawrence River System* are detailed in three reports: *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996); *Great Lakes System Flood Levels and Water Related Hazards* (MNR, February 1989), and the *St. Lawrence River Flood Levels* (Environment Canada, July 1993).

II) Flood Allowance For Wave Uprush and Other Water Related Hazards

- **Wave Uprush**

In areas susceptible to wave action, shoreline flooding hazards extend landward beyond the 100 year flood level to the limit of wave action. All shorelines of the *Great Lakes - St. Lawrence River System* and *large inland lakes* should be considered susceptible to wave action unless site specific studies using accepted engineering principles demonstrate that wave action is not significant.

Wave action includes wave setup, wave uprush, wave spray and/or wave overtopping. Wave setup is the mean increase in water level caused by the onshore transport of water due to waves breaking at the shoreline. Strictly speaking, wave uprush is the time varying height above the mean water level that the water runs up the shoreline face. However, methodologies for calculating wave uprush include wave setup.

For straight, uniform shoreline reaches without protection works, the landward limit of wave action can be represented by the maximum limit of wave uprush. In areas where waves act on shore protection works and other structures (e.g., docks), and in areas with irregular shorelines, the wave action may include wave spray and wave overtopping which are more difficult to determine and may require detailed study.

Wave spray has frequently been observed to go over and past many existing shoreline houses, cottages and other such structures. The landward extent and quantity of wave spray depends on such factors as the type of shore, nearshore bathometry, type of protection works, size of incident waves and wind conditions. Generally, during storms a significant amount of wave spray will occur behind structures that are near vertical and subjected to large breaking waves.

- **Other Water Related Hazards**

A number of additional water related influences impact on the landward extent or destructive nature of flood hazards. These include, but are not limited to, ship-generated waves, ice piling, and ice jamming.

For the connecting channels of the *Great Lakes - St. Lawrence River System, flooding hazards* may be the result of ship-generated waves rather than wind generated waves. However, for those portions of the connecting channels having fetch lengths, wind generated waves should be calculated, or depth-limited wave conditions assumed, to determine the wave uprush offset allowance.

Ice piling results from wind blowing over the ice and pushing it landward. This produces ridging and a large build-up of ice at the shore. In some instances, shore ice has exceeded 5 metres in height and extended landward up to 45 metres. Shore ice can scour sections of the onshore and nearshore as well as destroy structures close to the shore. It can also remove boulders from shallow areas, thereby reducing the level of natural shore protection.

Ice jamming, the build-up of ice at the outlets of the lakes into the connecting channels and the outlets of rivers into the lakes, can cause extensive damage to shore structures and nearshore profiles. At the same time, ice jams can pose problems by impeding water flows outletting from the lakes and into the connecting channels causing varying magnitudes in lake level increases depending on the size and duration of the ice jam blockage.

- **Determination of Flood Allowance for Wave Uprush and Other Water Related Hazards**

Implementing agencies may have difficulty, due to a lack of technical information, in calculating a flood allowance for wave uprush and other water related hazards.

In the absence of studies using accepted engineering principles, the suggested approach to determine the flood allowance for wave uprush and other water related hazards includes:

- for ***Great Lakes - St. Lawrence River System:***
  - **15 metre flood allowance measured horizontally from the 100 year flood level on lakes Superior, Huron, St. Clair, Erie and Ontario (Figure 3); or**
  - **5 metre flood allowance measured horizontally from the 100 year flood level on the connecting channels (Figure 4).**

- for ***large inland lakes:***
  - **5 metre flood allowance measured horizontally from the 100 year flood level (Figure 5)**

Figure 3: Flood Allowance for Wave Uprush and Other Water Related Hazards: Great Lakes

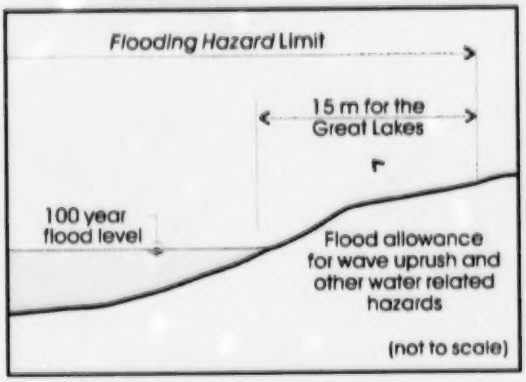

Flooding Hazard Limit
15 m for the Great Lakes
100 year flood level
Flood allowance for wave uprush and other water related hazards
(not to scale)

Figure 4: Flood Allowance for Wave Uprush and Other Wave Related Hazards: Connecting Channels

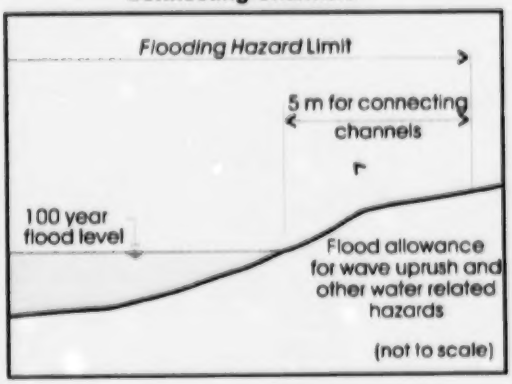
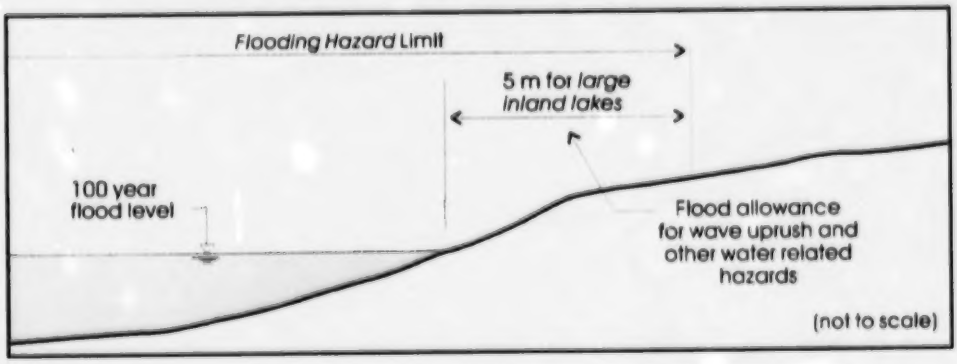

Flooding Hazard Limit
5 m for connecting channels
100 year flood level
Flood allowance for wave uprush and other water related hazards
(not to scale)

Figure 5: Flood Allowance for Wave Uprush and Other Water Related Hazards: *Large Inland Lakes*


Flooding Hazard Limit
5 m for large inland lakes
100 year flood level
Flood allowance for wave uprush and other water related hazards
(not to scale)

Where municipalities and planning boards determine that the suggested 15 metre and/or 5 metre flood allowances are either too great or not sufficient enough to address the severity of the shoreline flooding hazards, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using accepted engineering principles to determine the appropriate flood allowance for wave uprush and other water related hazards.

Where studies have been approved by the municipalities and planning boards, the *flooding hazard* limit should then be determined by the:

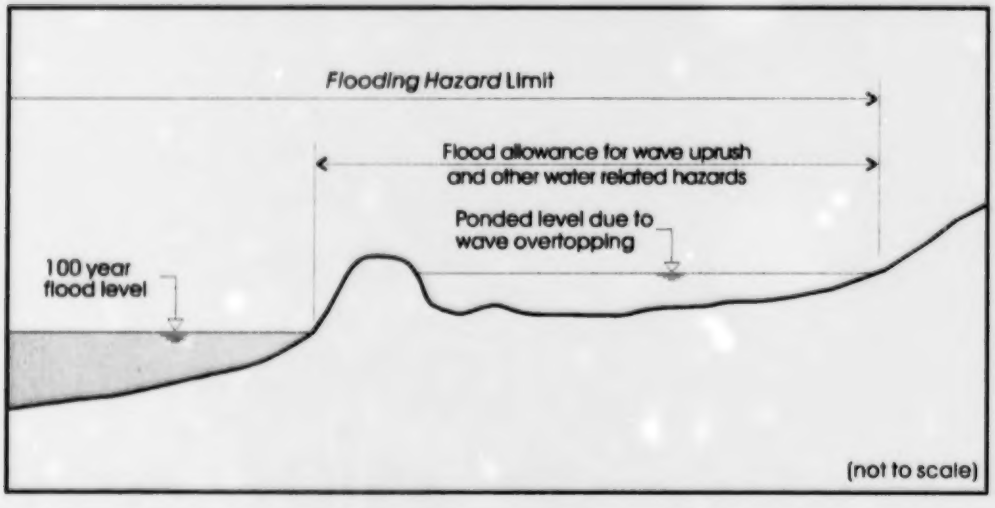
100 year flood level	+	**engineered flood allowance for wave uprush and other water related hazards**

and applied only to the area studied.

In shoreline areas **where wave uprush overtops a bank or protection works causing ponding landward of the 100 year flood level** thereby posing a potential long-term *flooding hazard* to the area:

- **the flood allowance for wave uprush and other water related hazards should be determined by a study using accepted engineering principles (Figure 6).**

Figure 6: *Flooding Hazard* Limit: Wave Uprush Overtops a Bank or Protection Works


Flooding Hazard Limit
Flood allowance for wave uprush and other water related hazards
Ponded level due to wave overtopping
100 year flood level
(not to scale)

Given the diversity of protection works (e.g., height, length, design, etc.) and naturally occurring shoreline banks that may result in ponding posing a long-term flood risk to the area, it is impractical to develop a single suggested approach which would recognize the uniqueness of each individual situation and the level of flood risk to be addressed. For this reason, in situations where wave overtopping causes ponding (i.e., long-term flood risk) a study should be undertaken to determine the "flood allowance for wave uprush and other water related hazards".

Although all three components (i.e., 100 year flood level, wave uprush and other water related hazards) should be calculated when determining the landward limit of the shoreline *flooding hazard*, the methods of calculation, the level of influence each factor poses, and the determination of which methods of calculation are acceptable differ depending on the type of shoreline being examined. For example, the calculation of wave action on a shoreline protected by a vertical wall, sloped revetment, beach or a bluff would all differ significantly.

For additional information related to calculating the *flooding hazard* limit and understanding what is considered "accepted engineering principles" in the sense of what methodologies are considered appropriate for use in a given situation(s) and the appropriateness and applicability of study results, the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996; Part 3: Flooding Hazards), the *MNR Technical Guide for Large Inland Lakes Shorelines (1996)* and *Wave Uprush and Overtopping: Methodologies and Applications (Atria 1997)* should be consulted.

b) *Erosion Hazards*

All shorelines, including bedrock shorelines, should be considered to be subject to erosion. Although the perception is that bedrock shorelines do not erode, this is not always the case. For instance, field investigations and measurements have indicated that some "soft" bedrock formations erode or recede at about the same average distance or rate per year as more stable cohesive shorelines. Where "hard" or more resistant bedrock formations exist, the rate of shoreline recession may not be as easily evident and may instead be measured in terms of change over periods of decades rather than years.

For all types of shorelines, what is at issue is the rate or speed of erosion that takes place on a given stretch of shoreline and the resultant risk or threat posed to life and property.

In defining and delineating areas experiencing shoreline erosion there should first be an understanding of what causes erosion, which landforms are more likely to erode, and what general slope failure mechanisms influence rates and magnitudes of slope recession.

Erosion in a shoreline environment results from two basic causes:

- forces of nature acting along the shoreline; and
- the actions of humans.

The natural causes of erosion may include processes such as wind, waves, rain striking exposed bluff faces, surface and subsurface drainage, ice action and slumpage.

Each of these naturally occurring erosive forces in turn pose different magnitudes of influence on a shoreline landform depending on such factors as:

- characteristics of submarine topography;
- width and slope of beaches fronting shore bluffs;
- extent, type and maintenance of slope vegetation;
- duration and frequency of prevailing winds;

- direction of wind fetches; and
- shoreline alignment.

Erosion susceptibility is further complicated by the mechanical properties of the landform requiring an understanding of such factors as resistibility of the landform to erosion (e.g., soil properties such as compressive strength, tensile strength, abrasive hardness, etc.) and slope stratigraphy.

The influence of human action on shoreline erosion is usually evident where human-designed erosion protection works or mitigation projects have not taken into account the complex interrelationships of the physical processes impacting not only in the immediate vicinity of the project itself but also those impacting on updrift and downdrift shoreline areas.

As such, by definition, the *erosion hazard* limit should be based on three components:

- **stable slope allowance**
- **average annual recession**
- **erosion allowance**

To address the variable nature of the *Great Lakes - St. Lawrence River System* and *large inland lakes* shorelines, the landward limit of the *erosion hazard* should be defined through the use of the following suggested **two step process**.

The **first step** involves the selection of one of the following two options:

stable slope allowance	+	**100 times the average annual recession rate** (e.g., 100 year recession) for shorelines **where a minimum of 35 years of reliable recession information is available** (Figure 7)

measured landward from the toe of the shoreline cliff, bluff, or bank;

OR

stable slope allowance	+	**erosion allowance** of: **30 metres** on the *Great Lakes - St. Lawrence River System*, **or** **15 metres** on *large inland lakes* **where there is insufficient recession rate information** (Figure 8)

measured landward from the toe of the shoreline cliff, bluff, or bank.

Figure 7: Stable Slope Allowance plus 100 times the Average Annual Recession Rate

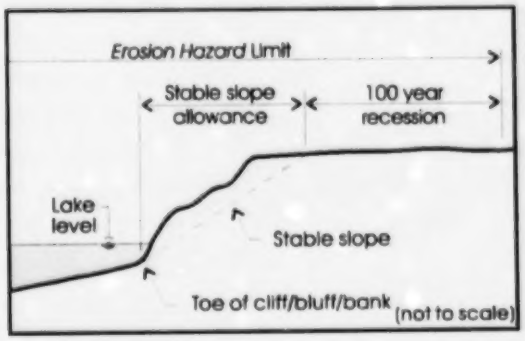
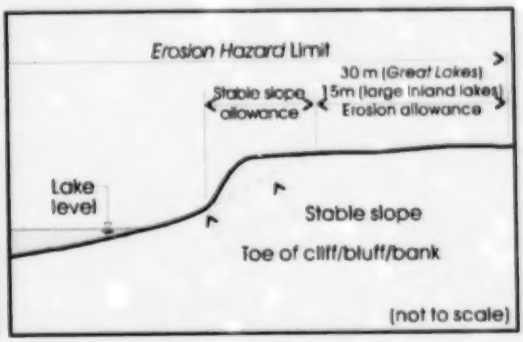


Figure 8: Stable Slope Allowance plus 30 Metres (Great Lakes) or 15 Metres (*Large Inland Lakes*) Erosion Allowance



The **second step** then involves the comparison of the selected option from the first step with:

- a **30 metre erosion allowance** for the *Great Lakes - St. Lawrence River System* (Figure 9) **or** a **15 metre erosion allowance** for *large inland lakes* (Figure 10), measured landward from the top of the shoreline cliff, bluff, or bank or the first landward break in slope.

Under the second step, it is the greater of the landward measurements from steps 1 and 2 which should ultimately determine the landward limit of the *erosion hazard*.

Figure 9: 30 Metre Erosion Allowance: Great Lakes

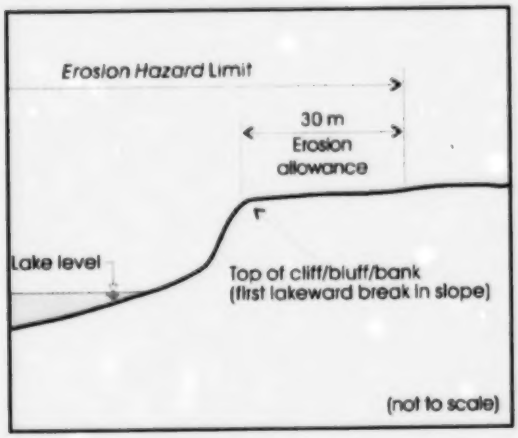
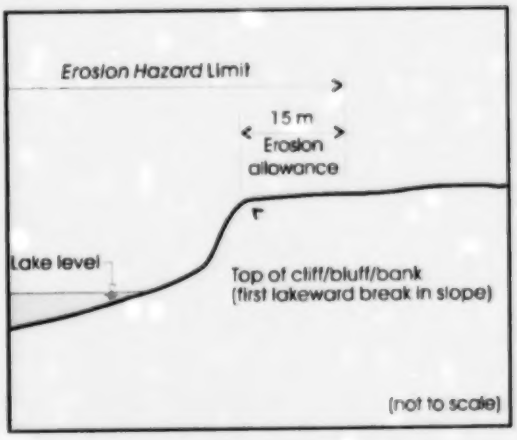


Figure 10: 15 Metre Erosion Allowance: *Large Inland Lakes*



For information related to defining and delineating shoreline erosion hazards, a number of sources of erosion information should be consulted including:

- consolidation of all erosion/recession rate information (MNR, August 1995);
- average annual recession rates (*Great Lakes Shoreline Classification and Mapping Study: Canadian Side*, Geomatics and Dr. Robin Davdison-Arnott 1992; and *Littoral Cell Definition and Sediment Budgets for Ontario's Great Lakes*, Reinders 1988);
- *Canada/Ontario Great Lakes Erosion Monitoring Program* document summarizing the monitoring station databases (Boyd 1981);
- *Coastal Zone Atlas* (federal/provincial publication 1976);
- photogrammetric cross-sections (Coastal Zone Atlas, FDRP Shoreline Hazard Mapping); and
- aerial photographs (e.g., displaying actual historical change over time).

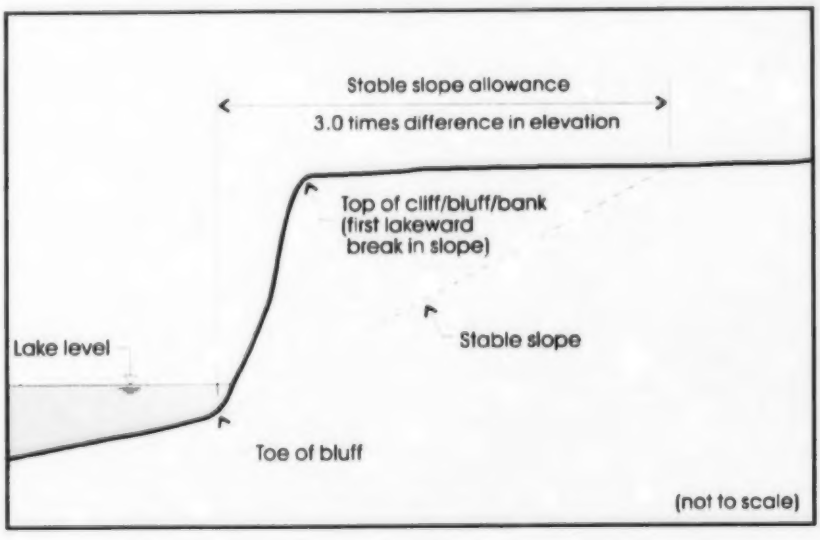
For additional information on the technical aspects of defining erosion hazards, data sources, the suitability and appropriateness of data and map sources, and the accepted methods of calculating and delineating erosion hazards the *MNR Technical Guide for the Great Lakes - St. Lawrence River Shorelines (1996)* and the *MNR Technical Guide for Large Inland Lakes Shorelines (1996)* should be consulted.

i) Stable Slope Allowance

The stable slope allowance should be determined as follows:

- a **horizontal allowance** measured landward from the toe of the shoreline cliff, bluff, or bank equivalent to **3.0 times the height of the cliff, bluff, or bank** (e.g., difference in elevation between the top or first lakeward break in slope and the toe of the shoreline cliff, bluff, or bank which may or may not be above or below the water level) (Figure 11)

Figure 11: Stable Slope Allowance



Where municipalities and planning boards determine that the 3:1 stable slope allowance is excessive or not sufficient enough, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using accepted geotechnical principles to determine the stable slope allowance. This flexibility may not be warranted or desired where a more precise definition of the *erosion hazard* is not necessary, where there is sufficient area within the development lot to site any proposed development outside of the *erosion hazard* limit, where development pressure is low and alternative development sites exist, or where the staff, administrative and financial resources within the municipality may preclude the ability of the municipality to support such studies.

Where studies using accepted geotechnical principles are approved by the municipalities or planning boards, the landward limit of the *erosion hazard* should then be defined by:

engineered stable slope allowance	+	**100 year recession rate**
	OR	
engineered stable slope allowance	+	**an erosion allowance of** **30 metres** on *Great Lakes - St. Lawrence River System* **or** **15 metres** on *large inland lakes*

and applied only in the area studied.

For additional information on what is considered "accepted geotechnical principles" in the sense of what methodologies are considered appropriate for use in a given situation(s) and the appropriateness and applicability of study results, the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996; Part 4) and supporting *Geotechnical Principles for Stable Slopes* (Terraprobe 1997) should be consulted.

ii) Erosion Allowance

Given that some types of shorelines may be inherently less susceptible to erosion than others, the planning process should provide the flexibility, where appropriate, to consider a reduction in the erosion allowance (i.e., 30 metres on the *Great Lakes - St. Lawrence River System* and 15 metres on *large inland lakes)* through the use of a study using accepted scientific and engineering principles. In specific, this may be considered appropriate in those situations involving highly stable bedrock shorelines, the lower shoreline profiles bordering the connecting channels and Lake St. Clair, and along naturally, well-sheltered shorelines.

Conversely, recognizing that there are uncertainties associated with less stable shoreline features (e.g., cohesive or non-cohesive bluffs and banks) on open lake environments, the flexibility to undertake studies to reduce the erosion allowance should not be considered. In fact, in highly unstable shorelines (e.g., fine-grained cohesive materials) an increase in the erosion allowance may be warranted.

For those situations where a municipality or planning board determines that a study may be used to define a reduced erosion allowance on highly stable bedrock shorelines, connecting channels, Lake St. Clair and naturally, well-sheltered shorelines, and conversely, an increased erosion allowance in highly unstable shoreline areas, the study should be undertaken using accepted scientific and engineering principles.

Where the municipality or planning board approves the study undertaken using accepted scientific and engineering principles, the landward limit of the *erosion hazard* should then be based on:

an **allowance for stable slope**	+	**approved scientific and engineering erosion allowance**

and applied only in the area studied.

For additional information on what is considered "accepted scientific and engineering principles" in the sense of what methodologies are considered appropriate for use in a given situation(s) and the appropriateness and applicability of study results, the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996) should be consulted.

c) *Dynamic Beach Hazards*

A shoreline beach is simply an accumulation of detrital material or sediment along a Great Lake, connecting channel, or large inland lake that has been transported and deposited by waves and by wind and/or wave generated currents. The sediment composition of a beach may consist of a variable mixture of sand, gravel, cobbles and/or boulders and may contain varying amounts of shell fragments.

Shoreline beach profiles are physical features experiencing constant change. Nearshore beach sediment, readily visible during low wave conditions, often may be transported offshore during storm events, only to be returned during periods of calmer weather and deposited by wind and wave action landward of the nearshore beach in the form of dune complexes. Some of the sand may be stored in the dune complexes for years during low lake levels and then returned to the water by storm wave action during periods of high lake levels.

As such, shoreline beach profiles are "dynamic" in nature, being shaped and re-shaped on a range of timescales that extend from either hours or days to years and decades in response to changing wave, wind and water level conditions and to changes in the rate of sediment supply to a particular stretch of shoreline.

An important consequence of these changes is that the elevation of any point on the dynamic beach profile is not a constant, but varies over time. This then precludes the appropriateness of defining the limit of the *dynamic beach hazard* in terms of a single elevation.

The factors controlling the dynamic nature of a beach environment are numerous and their interaction produces a highly complex set of processes and responses. In general terms, beach dynamics reflect the influence of processes such as wave-generated and wind-generated currents in the lake or connecting channel, transport of beach-building materials (e.g., sand, gravel) by wind on the sub-aerial part of the beach and dune, and the direct action of ice. The frequency and magnitude of these processes in turn are dependent on factors such as weather and climate, fluctuations in lake levels on a number of timescales (e.g., days, months, years), extent of winter ice cover, and the orientation and fetch of the beach. Finally, attributes of the beach itself, such as the size of the beach sediment, the sediment supply and beach sediment budget also act to determine the dynamic range of an individual beach.

Not all beaches are defined as "dynamic beaches". Although there may be surficial materials in the nearshore (e.g., beach deposits at the base of a bluff, cliff or bank) that are commonly referred to as "beaches", these types of beach environments may not be defined as "dynamic beaches" in the application of the *Provincial Policy Statement*.

For the purposes of clarification, *dynamic beach hazards* exist where:

- **beach or dune deposits exist landward of the water line (e.g., land/water interface); AND**
- **beach or dune deposits overlying bedrock or cohesive materials are equal to or greater than 0.3 metres in thickness, 10 metres in width and 100 metres in length along the shoreline; AND**
- **where the maximum fetch distance measured over an arc extending 60 degrees on either side of a line perpendicular to the shoreline is greater than 5 km. This normally does <u>not</u> occur where beach or dune deposits are located in embayments, along connecting channels and in other areas of restricted wave action where wave related processes are too slight to alter the beach profile landward of the waterline.**

Defining and delineating the *dynamic beach hazards* should include:

landward limit of the *flooding hazard* *100 year flood level* <u>plus</u> an allowance for wave uprush and other water related hazards	+	**dynamic beach allowance** of **30 metres** on the *Great Lakes - St. Lawrence River System* (Figure 12) **<u>or</u>** **15 metres** on *large inland lakes* (Figure 13)

Figure 12: ***Dynamic Beach Hazard Limit: Great Lakes - St. Lawrence River System***

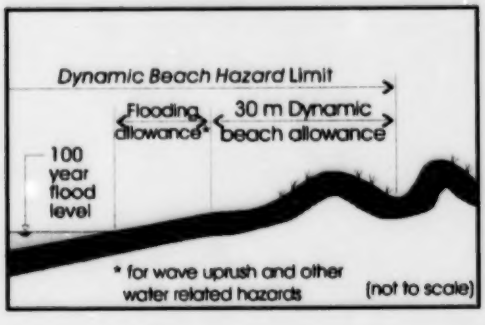
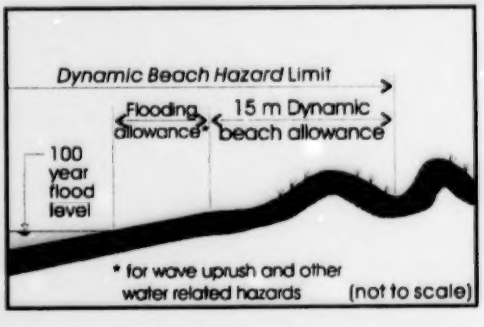

Dynamic Beach Hazard Limit
Flooding allowance*
30 m Dynamic beach allowance
100 year flood level
* for wave uprush and other water related hazards
(not to scale)

Figure 13: ***Dynamic Beach Hazard Limit: Large Inland Lakes***


Dynamic Beach Hazard Limit
Flooding allowance*
15 m Dynamic beach allowance
100 year flood level
* for wave uprush and other water related hazards
(not to scale)

For those situations where a municipality or planning board considers the dynamic beach allowance of 30 metres on the *Great Lakes - St. Lawrence River System* or 15 metres on *large inland lakes* to be excessive or not sufficient enough, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study, using "accepted scientific and engineering principles", to determine the landward limit of the "dynamic beach limit".

Where the "dynamic beach" is found to be erosional or receding, the landward limit of the *dynamic beach hazard* should then be defined as:

***flooding hazard* limit** 100 year flood level plus a flood allowance for wave uprush and other water related hazards	+	**a horizontal distance representing 100 times the average annual recession rate**	+	**dynamic beach allowance of 30 metres** for *Great Lakes - St. Lawrence River System* **or 15 metres** for *large inland lakes*

The calculation of this landward limit should involve a study using "accepted scientific and engineering principles" where a minimum of 35 years of reliable data does not exist.

Where the municipalities and planning boards approves a study using accepted scientific and engineering principles, the landward limit of the *dynamic beach hazard* should then be:

***flooding hazard* limit** 100 year flood level plus a flood allowance for wave uprush and other water related hazards	+	**scientific and engineered dynamic beach allowance** as determined by a study

and applied only in the area studied.

For additional information on what is considered "accepted scientific and engineering principles" in the sense of what methodologies are considered appropriate for use in a given situation(s) and the appropriateness and applicability of study results, the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996) should be consulted.

4.1.2 Hazardous Lands: *River and Stream Systems* (Policy 3.1.1 (b))

By definition, *river and stream systems* includes all watercourses, rivers, streams and small inland lakes (i.e., lakes having a surface area of less than 100 square kilometres that have a measurable and predictable response to a single runoff event).

River and stream systems are by nature dynamic, constantly changing landforms due mainly to the erosive forces of flowing water and the relative stability of surrounding slopes. The degree and frequency with which the morphological or physical change will occur in these systems depends on the interaction of a number of interrelated factors including hydraulic flow, channel configuration, sediment load in the system, and the stability of the banks, bed and adjacent slopes.

The *natural* importance of *river and stream systems* in providing physical, biological and chemical support functions for sustaining ecosystems, including that of humans, is indisputable. These functions are strongly associated with the physical processes of discharge (i.e., flow), erosion, deposition and transport that are inherent in any fluvial system. Given that ecological sustainability is based on the dynamic nature of these systems, it is essential that their physical processes (e.g., flow dynamics) be allowed to function in as natural a state as possible.

It is, however, the constant shaping and re-shaping of the *river and stream systems* by the physical processes associated with flooding, erosion and slope stability that result in the creation of hazardous conditions that pose a threat to human lives and cause property damages. Millions of dollars are spent annually in attempts to remedy flooding and erosion problems which pose a risk to life and property.

Defining the "area of provincial interest" within *river and stream systems* should first involve an understanding of the interrelationships between all of the physical processes acting on and influencing a particular system. These physical processes result from the interaction of numerous variables that comprise a watershed and/or fluvial system. These include, but are not limited to:

- geology (e.g., topography, lithology);
- climate (e.g., precipitation including rain/snow, temperature, wind);
- soil properties (e.g., structure, type, density, porosity);
- vegetation types (e.g., grasses, shrubs, trees, density/depth of root systems);
- hydraulic conditions (e.g., fluvial system);
  - discharge (i.e., volume per unit time)
    - low flow, peak discharge, bank full discharge, ephemeral or perennial flow
  - channel configuration
    - width vs. depth, slope, roughness, composition of the bed/bank material, pattern (e.g., braided, meandering, straight)
  - sediment load
    - bedload, suspended load, dissolved load
- hydraulic conditions (e.g., slopes); and
  - ground water regime (e.g., flow)
  - soil drainage (e.g., porosity)
    - overland flow, through flow, saturation flow
- slope stability.
  - height
  - inclination
  - loading
  - proximity to flowing water (e.g., potential for toe erosion)
  - water content

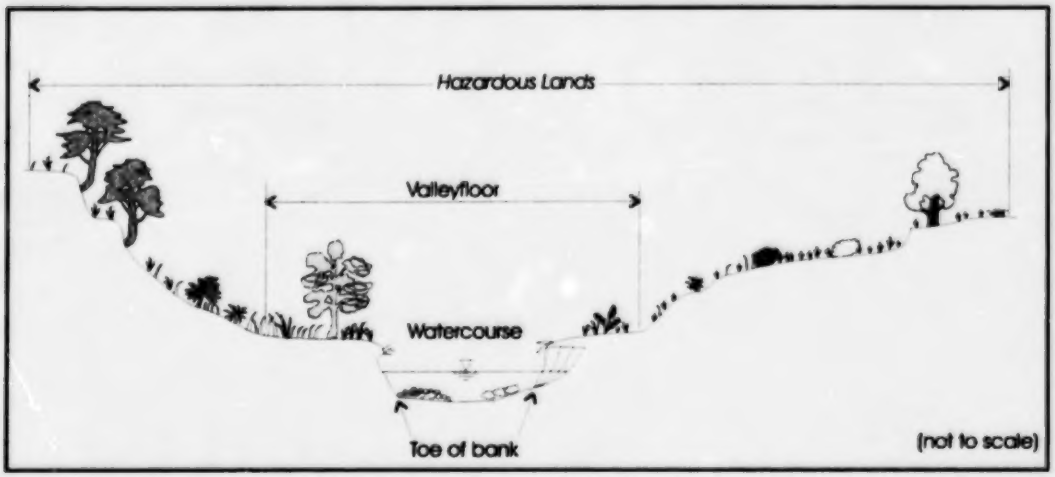
The complexity of the interaction of these variables in various *river and stream systems* results in a wide array of drainage and stream/river types (Leopold et al, 1964; Gregory and Walling 1974; Morisawa, 1985).

For *hazardous lands* associated with *river and stream systems* (Policy 3.1.1(b)), the numerous combinations of physical landforms have been simplified into three basic types:

- **confined system**;
- **unconfined system**; and
- **terrain-dependent system.**

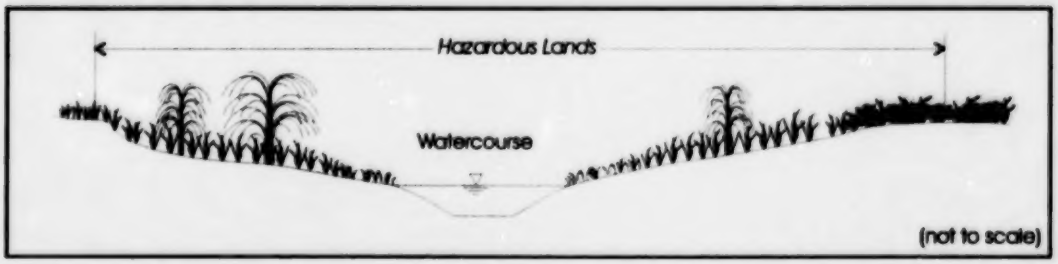
Confined *river and stream systems* are ones in which the physical presence of a valley corridor containing a river or stream channel, which may or may not contain flowing water, is visibly discernible (i.e., valley walls are clearly definable) from the surrounding landscape by either field investigations, aerial photography and/or map interpretation. The location of the river or stream channel may be located at the base of the valley slope, in close proximity to the valley slope (i.e., within 15 m) or removed from the valley slope (i.e., a distance greater than 15 m) (see Figure 14).

Figure 14: Confined *River and Stream Systems*



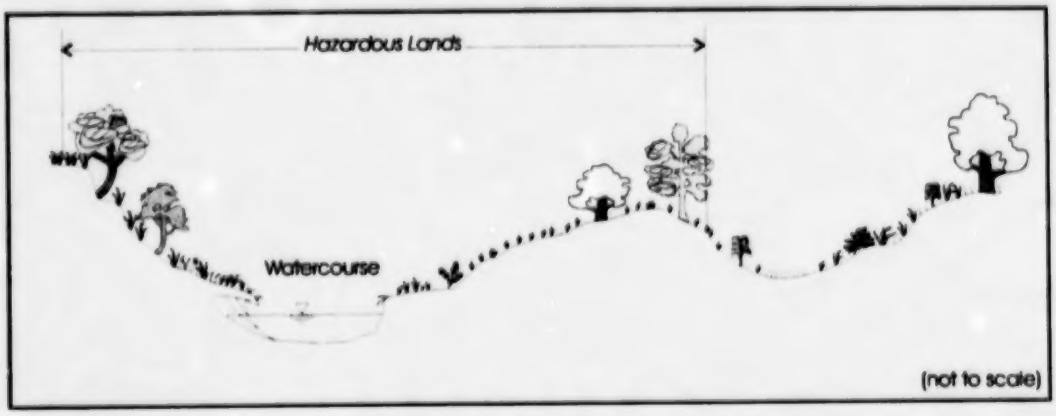
Unconfined *river and stream systems* are ones in which a river or stream is present but there is no discernible valley slope or bank that can be detected from the surrounding landscape by either field investigations, aerial photography and/or map interpretation. For the most part, unconfined systems are found in fairly flat or gently rolling landscapes and can be located within the headwater areas of drainage basins. The river or stream channels contain either perennial (i.e., year round) or ephemeral (i.e., seasonal or intermittent) flow and may range in channel configuration from seepage and natural springs to detectable channels (see Figure 15).

Figure 15: Unconfined *River and Stream Systems*



Terrain-dependent *river and stream systems* are ones in which the location of a river or stream feature is governed, or dependent on, the terrain or landscape characteristics (see Figure 16). For example, in areas dominated by large moraines, the location and/or shape of any rivers or streams traversing the area will be directly influenced by or are "dependent" on such factors as the composition and orientation of the moraine features or landscape. When terrain-dependent systems are located within areas dominated by cohesive materials (e.g., clay) they have features similar to, and often simulate, **confined systems.** Similarly, where terrain-dependent systems are located within areas dominated by cohesionless materials (e.g., sand) they have features similar to, and often simulate, **unconfined systems.**

Figure 16: Terrain-Dependent *River and Stream Systems*



By definition, the area of provincial interest, or *hazardous lands*, within confined, unconfined and terrain-dependent *river and stream systems*, should be based on the furthest landward limit of:

- ***flooding hazards***, and
- ***erosion hazards.***

a) *Flooding Hazards*

A natural phenomena in fluvial systems (i.e., rivers, streams) is the periodic overtopping of their banks and the flooding of adjacent lands (i.e., flood plains). The degree of flooding is dependent on the interaction of a number of variables associated with geomorphology (e.g., basin network shape, soils, geology, fluvial hydraulics) and climate (e.g., precipitation, snowmelt, ice jams, or a combination of these).

These variables, or characteristics, and the interactions between them will affect the way in which water responds in a flood situation. For example, topographical variations of a flood plain directly affect the nature and characteristics of a flood. The geomorphology, or shape and slope/gradient of the drainage basin, affect water velocity or speed and runoff volumes. Soils and geological factors affect water infiltration capabilities and ground water movement. In addition, the antecedent moisture conditions (i.e., general ability of the ground to absorb moisture based on the degree of saturation) affect whether the water (i.e., based on precipitation and snowmelt rates) infiltrates (i.e., unsaturated conditions) or runs off (i.e., saturated or frozen conditions) over the ground surface.

Historically, it has been estimated that the annual spring flood period in southern Ontario lasts for approximately 3 to 4 weeks. More recent studies have indicated that the significant and increasing urbanization along many of Ontario's larger riverine systems has reduced this flooding period to approximately 1 week, however, it now occurs several times rather than once a year. The result being a significant and increasing risk to life, property damage and social disruption. This is of particular concern in situations where numerous flood related factors and meteorological events combine to create a high magnitude flood event.

i) Flood Level

The "area of provincial interest" or that portion of a *river and stream system* that is susceptible to flooding (e.g., *flood plain*), should be based on a process of:

- identifying the **flood criteria** to be analyzed;
- selecting the **data required** for analysis; and
- computing the interaction of **flood magnitude** (i.e., discharge) and **hydraulic response.**

The following sub-sections provide a brief overview of each of the above matters. For more detailed information, the *MNR Technical Guide for River and Stream Systems* (1997) should be consulted.

• Flood Criteria

In Ontario, the *flooding hazards* limit, or *flood plain*, for *river and stream systems* should be based on the area of the Province in which the system is located and on the flood resulting from one of the following options (Figure 17):

- one of two storm-centred events:
  - **Hurricane Hazel** (1954)
  - **Timmins Storm** (1961)
- **100 year flood**; or
- a flood which is greater than the storm-centred events or greater than the 100 year flood and which was actually experienced in a particular watershed, or portion thereof as a result of ice jams, and which has been approved as the standard for that specific area by the Minister of Natural Resources.

A flood produced from Hurricane Hazel, or the Timmins Storm or an observed event are termed **event based floods** since their levels are recorded from surveyed high water marks, reliable reports, photographs and/or data publications. The known factors associated with these types of floods are transposed over the watershed or drainage area under investigation to determine the *flood plain* through hydraulic analysis. Conservation Authorities and/or the Ministry of Natural Resources may have information and data to assist in the calculation and application of event based floods to a particular watershed.

The flood produced by the 100 year flood is termed a **frequency based flood** which requires the collection, analysis and computation of a number of factors through hydrological modelling. This type of flood is based on a probability of occurrence of once every 100 years or a 1% chance of occurring in any given year.

A flood produced by a 100 year flood is considered to be the minimum standard for delineation of the *flooding hazard* limit (e.g., *flood plain*) for planning purposes in Ontario.

Figure 17: ***Flooding Hazard*** **Limit:** ***River and Stream Systems***

ZONE 1: Flood produced by the Hurricane Hazel Storm or the 100 Year Flood, whichever is greater

ZONE 2: 100 Year Flood

ZONE 3: Flood produced by the Timmins Storm or the 100 Year Flood, whichever is greater

- **Data Required**

To determine peak flows and to map their corresponding water surface elevations, it is necessary to obtain a considerable amount of data about the fluvial or river environment. Collection of all of the following information may not be necessary in every situation as the data requirements will vary dependent on the type of flood to be mapped, the characteristics of the location and the methodology (e.g., model) being applied. Generally, the data required should include, but may not be limited to:

- streamflow records;
- historical floods;
- specified meteorological events
  - storm-centred or regional events (e.g., Hurricane Hazel, Timmins Storm)
  - other storms with historical or designed precipitation and/or snowmelt rates;
- stage-discharge (e.g., water level-flow volume) relationships for each reach under investigation (e.g., historical records or as determined through field work);
- hydraulic characteristics of the fluvial system;
  - types of flow (e.g., Froude and Reynold's numbers)
  - stream energy (e.g., critical depth and velocity)
  - velocity profiles
- roughness (e.g., Manning's "n" equation; including size/shape of bed/ bank materials, size/shape of channel, channel sinuosity)
  - turbulence (e.g., affect on channel flow caused by natural (bed/bank materials) and artificial conditions (e.g., dams, diversions, bridges)
- cross-section surveying of channel and flood plain;
- elevation of high water marks (e.g., historical records or as determined through field work);
- aerial photograph interpretation;
- effect on discharge and flow caused by natural and artificial regulation (e.g., ice jams, lake levels, dams, dykes, etc.); and
- meteorological and physiographic characteristics of the watershed
  - drainage area, area of lakes and swamps, basin slope, channel slope and length, topography, soil types, vegetative cover, ground water levels and flow, land use, infiltration rates, soil moisture conditions, runoff, temperature, radiation data, snowmelt coefficients and lapse rates.

- **Flood Magnitude and Hydraulic Response**

The effect of an observed flood or frequency based flood on the extent of flooding in a riverine watershed is usually described in terms of the magnitude or discharge of the flood and the hydraulic response for the reach (e.g., water surface profile or level). This involves either conducting a flood frequency analysis (i.e., frequency based floods) to create a discharge/recurrence interval curve for flooding or determining runoff from a specified meteorological event (e.g., Hurricane Hazel, Timmins Storm or an observed flood) and applying or extending those results through mathematical models to a stage-discharge rating curve for the location.

The determination of flood magnitude and hydraulic response is normally achieved through the use of computer modelling. Models can range from being simplistic in nature to those that attempt to describe every aspect of the hydrologic cycle. Any model applied to a particular watershed should take into account the natural and artificial factors or data which have been determined to have a major influence on runoff characteristics and streamflow. Verifying the applicability of a model is also normally required and achieved by calibrating the calculated results with known observed results for a number of meteorological events.

There are numerous hydrologic computer models currently available. Information on the models considered to be acceptable for *flood plain* mapping in Ontario (e.g., HYMO, OTTHYM, GAWSER) may be available from the Ministry of Natural Resources and/or the local Conservation Authority.

b) *Erosion Hazards*

The three main forces that shape and re-shape *river and stream systems* are the natural processes of erosion, flooding (i.e., water flow), and slope stability. Erosion and slope stability are two natural processes which are quite different in nature yet often linked together. Erosion is essentially the continual loss of earth material (i.e., soil or sediment) over time as a result of the influence of water or wind. Slope stability, usually described in terms of the potential for slope failure, refers to a mass movement of earth material, or soil, sliding down a bank or slope face as a result of a single event in time.

By definition, the *erosion hazards* limit, depending on the type of *river and stream system* involved, should be based on the combined influence of:

- **toe erosion allowance**
- **stable slope allowance**
- ***flooding hazard* limit** or **meander belt allowance**
- **erosion access allowance**

Based on the type of *river and stream system* landform (i.e., confined, unconfined, or terrain-dependent), Figure 18 provides guidance on which combinations of these factors should be used in defining the *erosion hazards* limit.

Figure 18: ***River and Stream Systems*** **Landform Classification**

	Confined	Unconfined	Terrain-Dependent
Watercourse Profile			
Typical Geologic Setting	Valley corridors	Glaciated plains, flat to gently rolling	Rugged glaciated, hummocky, rolling

Hazard Allowances	Confined	Unconfined	Terrain-Dependent	
			Cohesive Soil	Cohesionless Soil
Stable Slope	Yes	No	Yes	No
Toe Erosion	Yes	No	Yes	No
Meander Belt	No	Yes	No	Yes
Access Allowance	Yes	Yes	Yes	Yes

Defining the *erosion hazards* limit for the three basic types of *river and stream systems* landforms should be based on the following):

- **confined systems** and **terrain-dependent systems** (i.e., those consisting of cohesive materials)(see Figures 19a and 19b)

toe erosion allowance* (from Table 2; OR 100 times the average annual recession rate of the toe) **OR** as determined by a study using accepted geotechnical and engineering principles	+	**allowance for stable slope** 3:1 (h:v) **OR** as determined by a study using accepted geotechnical principles	+	**erosion access allowance** 6 metres **OR** as determined by a study using accepted scientific, geotechnical and engineering principles

* Note:
- *where the soil type is not known, Table 2 recommends the use of a 15 m toe erosion allowance; and*
- *when using average annual recession rates to determine the toe erosion allowance a minimum of 25 years of reliable information is recommended.*

- **unconfined systems** and **terrain-dependent systems** (i.e., those consisting of cohesionless materials)(see Figures 20a and 20b)

an allowance for the *flooding hazard* limit OR meander belt allowance 20 times the bankfull channel width centred over the meander belt axis **OR** as determined by a study using accepted engineering principles	+	**erosion access allowance** 6 metres **OR** as determined by a study using accepted scientific, geotechnical and engineering principles

The following subsections clarify how each of these components for defining *erosion hazards* should be determined and where flexibility may be provided to undertake studies to address unique, local situations (e.g., where the approach(es) may be considered excessive or insufficient to define the area of provincial interest). Where studies using accepted scientific, geotechnical and/or engineering principles were used to determine the landward limit of the *erosion hazards* are approved by the municipality, they should be applied only within the area studied.

For additional information on what is considered "accepted scientific, geotechnical and engineering principles" in the sense of what methodologies are considered appropriate for use in a given situation(s), and the appropriateness and applicability of study results, the *Geotechnical Principles for Stable Slopes* (Terraprobe 1997) and the *MNR Technical Guide for River and Stream Systems* (1997) should be consulted.

Figure 19: ***Erosion Hazard Limit*: Confined and Terrain-Dependent (Cohesive) *River and Stream Systems***

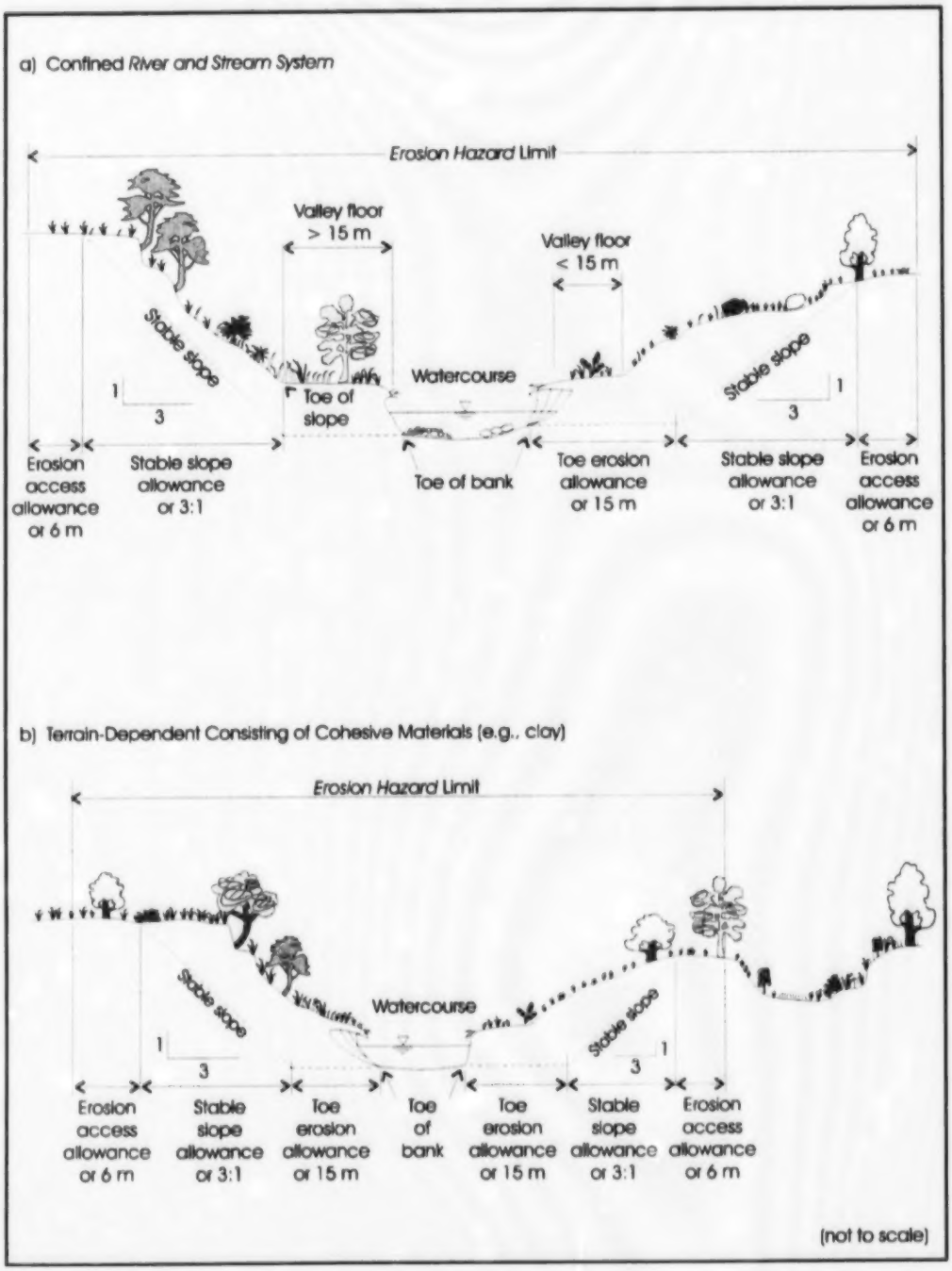
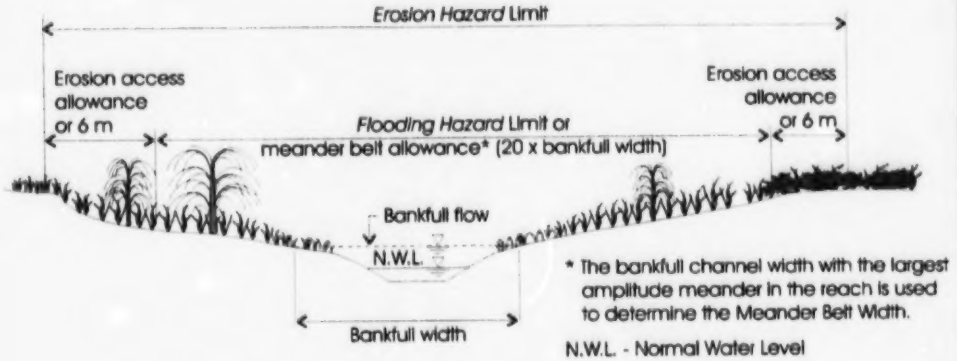
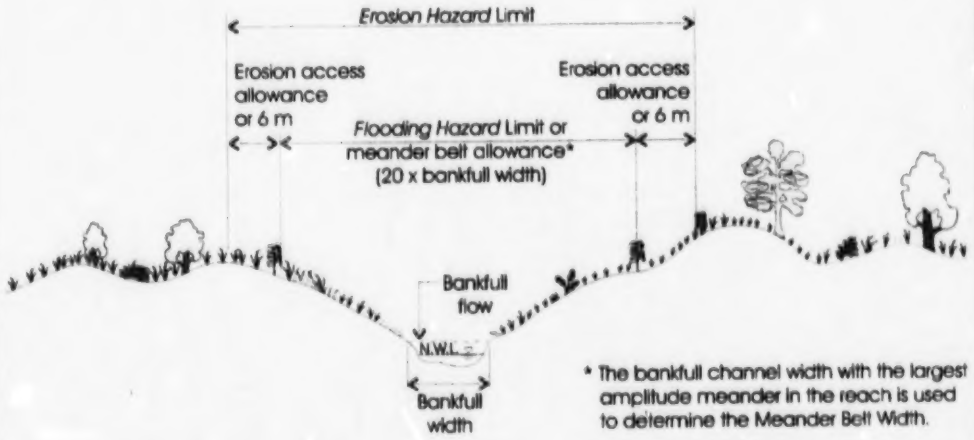


Figure 20: *Erosion Hazard* Limit: Unconfined and Terrain-Dependent (Cohesionless) *River and Stream Systems*

a) Unconfined *River and Stream System*


Erosion Hazard Limit
Erosion access allowance or 6 m
Flooding Hazard Limit or meander belt allowance* (20 x bankfull width)
Erosion access allowance or 6 m
Bankfull flow
N.W.L.
Bankfull width
* The bankfull channel width with the largest amplitude meander in the reach is used to determine the Meander Belt Width.
N.W.L. - Normal Water Level

b) Terrain-Dependent Consisting of Cohesionless Materials (e.g., sand)


Erosion Hazard Limit
Erosion access allowance or 6 m
Flooding Hazard Limit or meander belt allowance* (20 x bankfull width)
Erosion access allowance or 6 m
Bankfull flow
N.W.L.
Bankfull width
* The bankfull channel width with the largest amplitude meander in the reach is used to determine the Meander Belt Width.
N.W.L. - Normal Water Level

(not to scale)

i) Toe Erosion Allowance

The flow of water through *river and stream systems* can cause erosion of the surface or exposed face of the bank or channel. The magnitude or rate of erosion can be quite variable over the course of a year dependent on the volume, velocity and duration of the flows. For example, a heavy rainfall or rapid snowmelt event may increase the potential magnitude or rate of erosion as a result of a measurable increase in water flows or discharge into and through the *river and stream systems*. Areas which are particularly susceptible to erosion are those banks or valleys slopes on the outside of meanders or bends of the river or stream.

Erosion is also the result of the gradual and continuous removal of soil material through other processes which are not always easily discernible. For example, wind and ice action on a river bank or channel results in the weathering, dislodging and transport of soil particles. This constant, yet often slow removal, ultimately can lead to the undercutting and instability of an adjacent slope. The level or rate of toe erosion, in this instance, is a function of the amount of water flowing through the system, the presence, duration and force of the wind, and the varying influence of ice and other water related forces (e.g., ground water seepage, and piping).

The rate of erosion is also a function of the proximity of the river or stream channel to a valley wall or bank face. If the river or stream channel is in close proximity or abuts the valley wall the erosive forces of the flowing water will cause a steepening and then undercutting of the valley wall. The degree or severity of this erosive action is dependent on the soil composition (e.g., determines the strength or susceptibility of the slope) and the proximity and exposure of the slope to the channel or water flows.

The **toe erosion allowance** or recession of the toe of the slope, which is normally applied only to confined systems and terrain-dependent systems consisting of cohesive materials, may be determined in one of four ways:

- use of the **average annual recession rate** applies only to confined and terrain-dependent systems consisting of cohesive materials. A minimum 25 years of record or data is required to provide a measure of reliability when determining average annual recession rate extended over a 100 year planning horizon. Data sources could include survey information, aerial photographs and through field monitoring and measurement using equipment having sufficient precision and accuracy to provide a reliable indication of recession.

- use of a **15 metre toe erosion allowance** measured inland horizontally and perpendicular to the toe of the watercourse slope (Figure 19) where the valley floor is less than or equal to 15 metres (i.e., distance between the watercourse and the base of the valley wall). The proximity of the watercourse to the base of the valley wall can be determined from aerial photography or site investigations.

- **toe erosion allowance based on soil types and hydraulic processes** based on visual observations or analytical studies and where the valley floor is less than or equal to 15 metres (i.e., distance between the watercourse and the base of the valley wall). Use of this option is guided by the information outlined in Table 2.

- use of a study using accepted geotechnical and engineering principles and based on a minimum of 25 years of record or data.

Where the third option outlined above is selected (i.e., use of Table 2), there are a number of steps involved in determining the toe erosion allowance for a given location:

- Step 1: The native soil structure or composition of the site should be confirmed either through a site visit or previously generated information (e.g., borehole, auger hole or test pits). Select one of four general material types (i.e., hard rock; soft rock, cobbles and boulders; stiff/hard cohesive soils, coarse granular and/or tills; or soft/firm cohesive soil and/or fine granular) from Table 2.

Table 2: Determination of Toe Erosion Allowance

MINIMUM TOE EROSION ALLOWANCE - River Within 15 m of Slope Toe*					
	Type of Material Native Soil Structure	**Evidence** of Active Erosion** **OR** Bankfull Flow Velocity > Competent Flow Velocity***	**No evidence** of Active Erosion** **OR** Bankfull Flow Velocity <Competent Flow Velocity***		
			Bankfull Width		
			< 5m	5-30m	> 30m
1.	Hard Rock (granite) *	0 - 2 m	0 m	0 m	1 m
2.	Soft Rock (shale, limestone) Cobbles, Boulders *	2 - 5 m	0 m	1 m	2 m
3.	Stiff/Hard Cohesive Soil (clays, clayey silt) Coarse Granular (gravels) Tills *	5 - 8 m	1 m	2 m	4 m
4.	Soft/Firm Cohesive Soil, loose granular, (sand, silt) Fill *	8 - 15 m	1-2 m	5 m	7 m

* Where a combination of different native soil structures occurs, the greater or largest range of applicable toe erosion allowances for the materials found at the site should be applied

** **Active Erosion** is defined as: bank material is exposed directly to stream flow under normal or flood flow conditions where undercutting, oversteepening, slumping of a bank or down stream sediment loading is occurring. An area may have erosion but there may not be evidence of 'active erosion' either as a result of well rooted vegetation or as a result of a condition of net sediment deposition. The area may still suffer erosion at some point in the future as a result of shifting of the channel. The toe erosion allowances presented in the right half of Table 2 are suggested for sites with this condition.

*** **Competent Flow Velocity** is the flow velocity that the bed material in the stream can support without resulting in erosion or scour. For *bankfull width* and *bankfull flow velocity*, see Step 2 and Figure 20.

NOTE: for additional information related to the use and application of this Table the *MNR Technical Guide for River and Stream Systems* (1997) should be consulted.

Where there is evidence of high variability in soil composition, the soil composition is not known, and/or evidence of high erosion activity, the 15 metre toe erosion allowance should be applied.

- Step 2: Determine whether or not there is evidence of active erosion **OR** if the bankfull velocity is greater than the competent flow velocity. Visible on-site evidence of active erosion may include a bare or vegetation-free river or stream bank which is directly exposed to water flows, and where undercutting, over-steepening, slumping of the bank or high downstream sediment loading is occurring. Slumping, scars, and bare stream banks that are not directly exposed to river flows are slope stability issues and should not be considered as evidence of "active erosion" (see Figure 21, photos).

  Determination of whether the bankfull velocity is greater than the competent flow velocity can be confirmed through site investigations or the calculation of flow velocities (i.e., determined through the use of analytical hydrologic studies involving an assessment of flow data and flow model calculations).

  Where active erosion is confirmed (see Figures 21a and 21b) **OR** the bankfull velocity is greater than the competent flow velocity, and the native soil structure or composition is known, Table 2 provides the range of toe erosion allowance that should applied (e.g., for soft/firm cohesive soils (#4, left column) the toe erosion allowance should be within the range of 8-15 metres).

- Step 3: Where there is no evidence of active erosion (see Figure 21c) **OR** the bankfull velocity is less than the competent flow velocity, water depths should be used to determine the toe erosion allowance (e.g., area of stiff/hard cohesive soils (#3) and a bankfull width of 5 to 30 metres would result in the selection of a toe erosion allowance of 2 metres).

Where the use of any of the first three options suggests that the identified toe erosion allowance may be excessive or not sufficient enough to reflect location conditions, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using accepted geotechnical and engineering principles and a minimum of 25 years of record or data to determine the toe erosion allowance. Where the municipality or planning board approves the study using accepted geotechnical and engineering principles, the geotechnical/engineering toe erosion allowance should be applied only in the area studied.

In some locations studies of toe erosion allowances may have already been undertaken by local agencies. These allowances are generally unique to specific watersheds or regions and are usually based on the subsoil and ground water conditions characteristic of the area. Where local studies have been undertaken using accepted geotechnical and engineering principles they may be used to determine the toe erosion allowances for the area studied.

Figure 21: Erosion: *River and Stream Systems*

a) Active Erosion

b) Active Erosion

c) No Evidence of Active Erosion

ii) Stable Slope Allowance

The stability or instability of slopes is governed by the interrelationships between a number of variables associated with surface and subsurface conditions. These include, but are not limited to, soil composition, slope steepness or inclination, water content and movement through and over the slope, load or pressures on the slope, and the presence or proximity of flowing water. Slope movement or instability can occur in many ways. The most common causes of slope movement include:

- changes in slope configuration (e.g., steepness, inclination);
- increases in loading on a slope (e.g., placement of buildings, structures or fill at or near the crest of the slope);
- changes in surface/subsurface drainage of the soil resulting in higher levels of flows and erosive action or higher water pressures (e.g., heavy rainfall, blocked drainage); and
- loss or removal of stabilizing vegetation (e.g., weakening of the soil structure with the removal of the surface cover and root systems).

Naturally occurring erosion processes can also play an integral role in affecting the stability of a slope. This is particularly true where flowing water is involved (e.g., surface runoff over the slope, seepage zones associated with throughflow and ground water flow). Examples of the effects of flowing water on slope stability include, but are not limited to:

- slope failure caused by erosion at the toe of the slope as evidenced by the undercutting and steepening of the slope by river or stream flows or wave action at the base of the slope;
- saturation and resultant weakening of the strength of the soil structure (e.g., slope face) related to water seepage or the presence of ground water flow; and
- "piping", associated with springs or seepage areas, on the slope face which may cause erosion to occur in the weaker layer of soil (e.g., sand) overlying a less permeable soil type (e.g., clay).

The determination and use of a stable slope allowance (Figure 19) should apply only to confined systems and terrain-dependent systems consisting of cohesive materials. By definition, unconfined systems and terrain-dependent systems consisting of cohesionless materials do not have discernible valley or channel slopes and as such, do not usually have significant slope stability concerns.

The **stable slope allowance** should be determined using:

- **a horizontal allowance measured further landward from the toe erosion allowance (i.e., horizontally and perpendicular from the toe of the watercourse) equivalent to 3.0 times the height of the slope** (see Figure 19)

OR

- **a stable slope allowance determined by a study using accepted geotechnical principles.**

Where municipalities and planning boards determine that the 3:1 (h:v) stable slope allowance is excessive or not sufficient enough, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using accepted geotechnical principles to determine the stable slope allowance. This flexibility may not be warranted or desired where a more precise definition of the *erosion hazards* is not necessary, where there is sufficient area within the development lot to site any proposed development outside of the *erosion hazards* limit, where development pressure is low and alternative development sites exist, or where the staff, administrative and financial resources within the municipality may preclude the ability of the municipality to support such studies.

For those situations where a study is used to determine the "stable slope allowance", the study should be undertaken using "accepted geotechnical principles". Where studies using accepted geotechnical principles are approved by the municipalities or planning boards, the engineered stable slope allowance should be applied only in the area studied.

iii) *Flooding Hazard* Limit Allowance and Meander Belt Allowance

Use of the *flooding hazard* limit or meander belt allowance is normally applied only to unconfined *river and stream systems* and terrain-dependent *river and stream systems* consisting of cohesionless materials. The general intent of defining the *flooding hazard* limit or meander belt allowance within these types of *river and stream systems* is to ensure that the flow of water and its associated natural processes, including erosion, are maintained (see Figures 20a and 20b).

As unconfined systems and terrain-dependent systems consisting of cohesionless materials are generally found within relatively flat terrains it is important to recognize that natural hazards associated with these fluvial systems may extend well beyond the immediate channel under conditions such as heavy or rapid runoff or spring snowmelt. During these times of increased flows, water flow may overtop banks of channels, create new channels and/or cause flooding and erosion.

Where the *flooding hazard* limit plus the erosion access allowance is used to determine the *erosion hazard* limit, the existence and availability of applicable data normally limits its use to drainage basins of greater than 125 hectares.

- **Meander Belt Allowance**

In any fluvial system, the morphology or change of the channel is a result of the dynamic balance of energy (e.g., flow or discharge of water) and the resistance of material comprising the channel perimeter (Morisawa 1985). As such, the channel form (e.g., shape, size, configuration) is governed by its need to carry sediment load (e.g., bed, suspended and dissolved) using the availability of water flows or discharge. A change in any of the variables (e.g., discharge, load, resistance) will result in a change in the channel form. One result of this change may be a shifting of the watercourse channel causing a change in the meander or channel orientation or form.

Unconfined *river and stream systems* and terrain-dependent systems consisting of cohesionless materials are often located within relatively flat terrain. They normally contain perennial (i.e., year round) or ephemeral (i.e., intermittent) flows which have a tendency to constantly shift or meander (i.e., laterally and downstream) in response to the continuous changes associated with the natural influence of discharge and load.

The term **meander belt allowance**, for the purposes of defining the "area of provincial interest", is essentially the maximum extent that a water channel migrates. The term meander belt is derived from terminology used to describe meandering systems such as amplitude, wavelength, bend radius, bankfull width, point bars, pools, riffles and concave and convex banks (see Figure 22).

A meandering system is comprised of a series of interconnected reaches. A reach is defined as a length of channel over which the channel characteristics are stable or similar. For each reach, the meander belt can conceptually be centred on a line or axis drawn through the middle of the meanders or riffle zones, a line that essentially divides each of the meanders in half (Figure 23).

Figure 22: Meandering System: Terminology

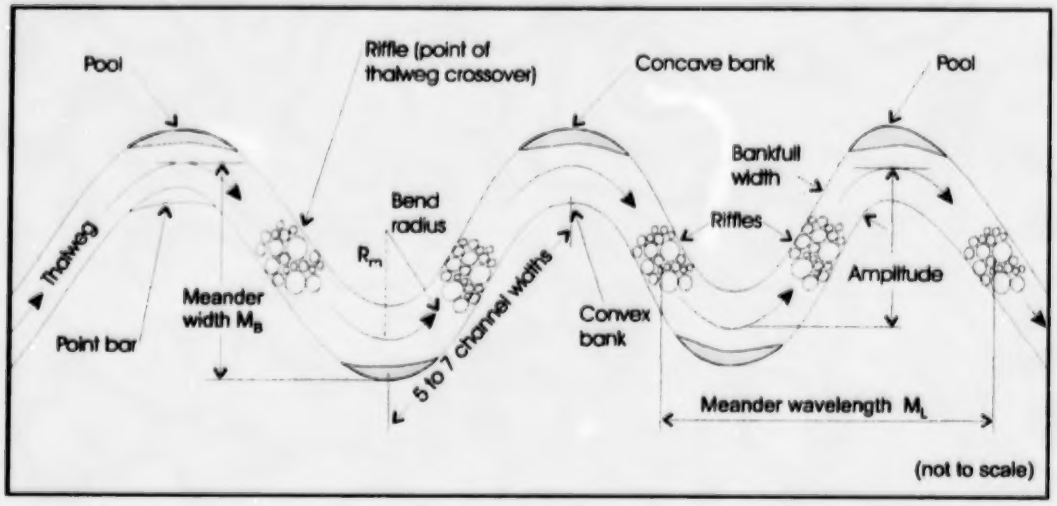
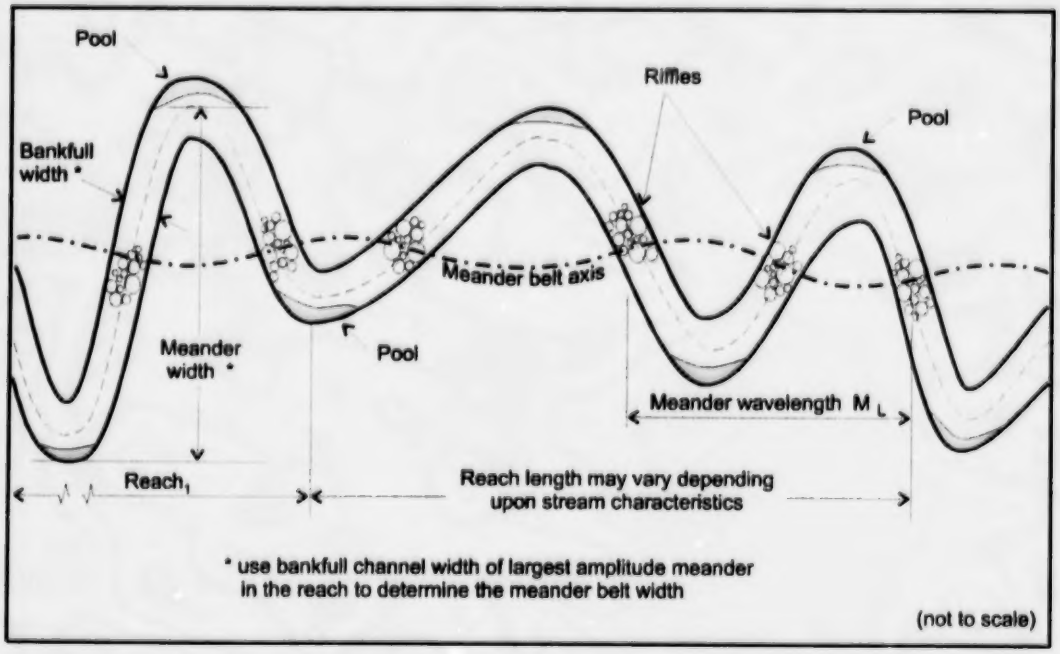
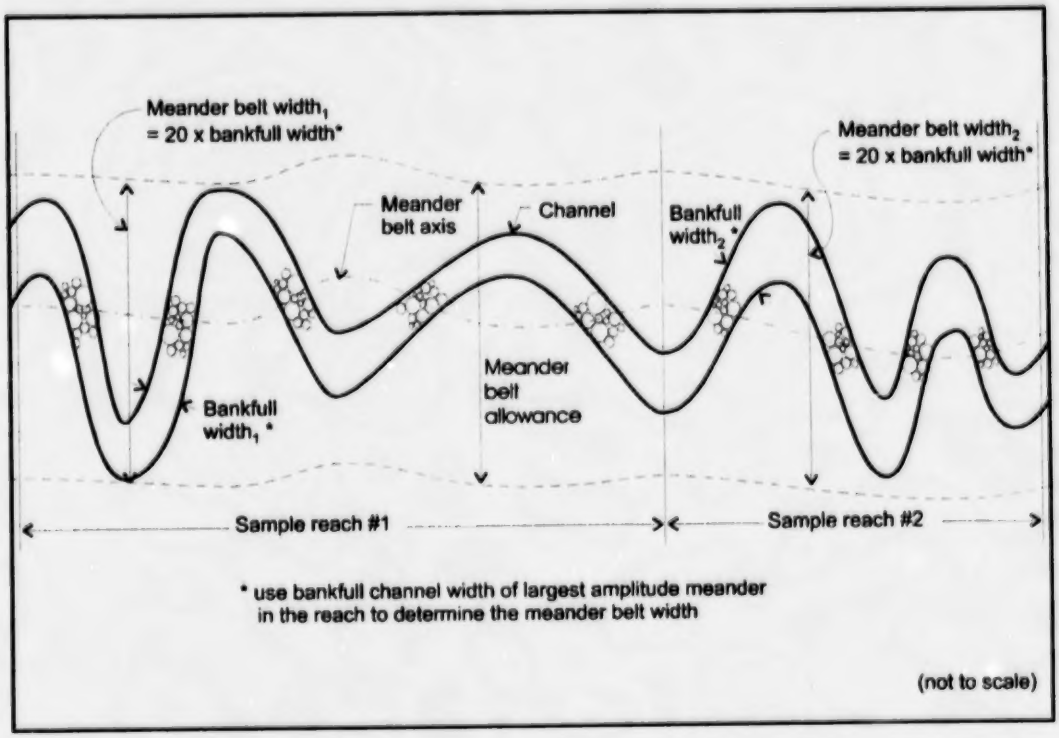


Figure 23: Meander Belt Axis



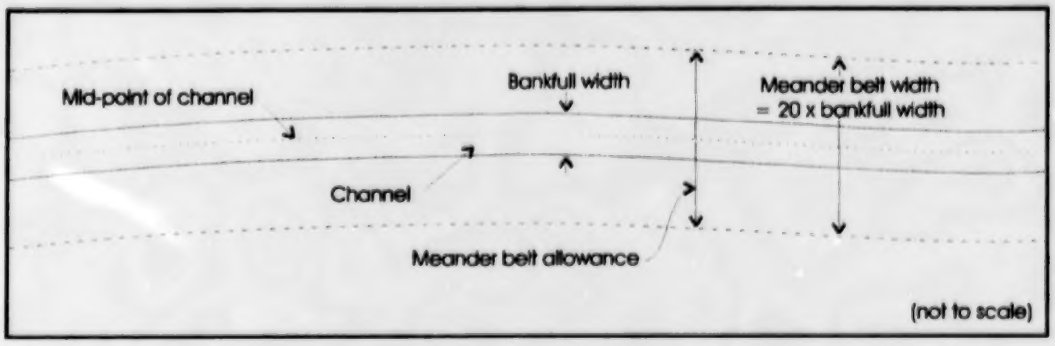
Numerous technical sources have indicated that the bankfull discharge is the main type of flow that determines channel morphology or change. As such, the width of the meander belt is derived from an analysis of the bankfull channel width of the largest amplitude meander in the reach. Bankfull channel width may be determined through either field investigations or through aerial photograph interpretation. Based on available data and information the **meander belt allowance** should be defined as **20 times the bankfull channel width of the reach** and centred on the meander belt axis (Figure 24).

Figure 24: Meander Belt Allowance


Meander belt width$_1$
= 20 x bankfull width*
Meander belt width$_2$
= 20 x bankfull width*
Meander belt axis
Channel
Bankfull width$_2$ *
Bankfull width$_1$ *
Meander belt allowance
Sample reach #1
Sample reach #2
* use bankfull channel width of largest amplitude meander in the reach to determine the meander belt width
(not to scale)

For those reaches where the channel appears to be straight (Figure 25), numerous factors combine to influence the size, shape and location of the meanders or the channel. For example, the "straightness" of the channel may result from the channel bed being located in a less erosive soil structure. Over time, flows within the channel bed may expose a more erosive soil structure and the channel may again begin to form meanders. When applying the meander belt allowance of 20 times the bankfull channel width for a reach that appears to be relatively straight, the meander belt should be centred on the mid-line of the channel.

Figure 25: Straight Channel: Meander Belt Allowance



Combining all of the calculated meander belt widths for each reach together along the entire length of channel will provide the overall meander belt allowance for the unconfined system (see Figure 24).

Where municipalities and planning boards determine that 20 times the bankfull channel width of the reach is excessive or not sufficient enough in determining the meander belt allowance, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using accepted scientific, and engineering principles to determine the meander belt allowance. This flexibility may not be warranted or desired where a more precise definition of the meander belt allowance or *erosion hazard* limit is not necessary, where there is sufficient area within the development lot to site any proposed development outside of the *erosion hazard* limit (i.e., meander belt allowance plus the erosion access allowance), where development pressure is low and alternative development sites exist, or where the staff, administrative and financial resources within the municipality may preclude the ability of the municipality to support such studies.

For those situations where a study is used to determine the "meander belt allowance", the study should be undertaken using "accepted engineering principles". These studies usually involve a range of variables including, but not limited to:

- discharge regimes;
- slope, sinuosity, width-to-depth ratios, particle size of sediment in river/stream beds and banks, stream entrenchment ratios, and landform feature/stability class;
- drainage areas and patterns of the system;
- determination of the meander pattern (e.g., amplitude, radius of curvature, meander length, concave and convex banks, spacing of pool and riffle zones, and the presence or remnant meanders or oxbow lakes);
- bedload, suspended load and dissolved loads;
- channel roughness and shear stress required to move sediment loads;
- bankfull discharge and channel determination; and
- potential for lateral or downstream migration of the meander belt allowance.

Some studies of meander belt allowances have already been undertaken by local agencies. These allowances are generally unique to specific watersheds or regions. Where local studies have been undertaken using accepted engineering principles they may be used to determine the meander belt allowance for the area studied.

iv) Erosion Access Allowance

The erosion access allowance is the last component used to determine the landward limit of the *erosion hazards* and should be applied within all confined, unconfined and terrain-dependent *river and stream systems*.

Three main principles support the inclusion of the erosion access allowance:

- providing for emergency access to erosion prone areas;
- providing for construction access for regular maintenance and access to the site in the event of an erosion event or failure of a structure; and
- providing protection against unforeseen or predicted external conditions which could have an adverse effect on the natural conditions or processes acting on or within an erosion prone area of provincial interest.

Study results using available data and information suggests that the **erosion access allowance** for *river and stream systems* should be **6 metres** (see Figures 19 and 20).

Where municipalities and planning boards determine that the suggested 6 metre erosion access allowance is excessive or not sufficient enough to provide the required public safety and site access, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using accepted scientific, geotechnical and engineering principles to determine the erosion access allowance. This flexibility may not be warranted or desired where a more precise definition of the erosion access allowance is not necessary, where there is sufficient area within the development lot to site any proposed development outside of the *erosion hazard* limit, where development pressure is low and alternative development sites exist, or where the staff, administrative and financial resources within the municipality may preclude the ability of the municipality to support such studies.

For those situations where a study is used to determine the "erosion access allowance", the study should be undertaken using "accepted scientific, geotechnical and engineering principles". Where studies using accepted scientific, geotechnical and engineering principles are approved by the municipality or planning boards, they should be applied only in the area studied.

Some studies of erosion access allowances have already been undertaken by local agencies. These allowances are generally unique to specific watersheds or regions. Where local studies have been undertaken using accepted scientific, geotechnical and engineering principles they may be used to determine the erosion access allowances for the area studied.

4.1.3 *Hazardous Sites* (Policy 3.1.1 (c))

Policies governing *hazardous sites* generally tend to include two broad types of natural hazards:

- **unstable soils**
  - sensitive marine clays (e.g., leda)
  - organic soils
- **unstable bedrock**
  - karst formations

a) Unstable Soils: Sensitive Marine Clays (Leda)

Sensitive marine clays, commonly known as leda clay, formed as a result of sedimentation processes in the Champlain Sea during the last glacial period. Over time, as the Champlain Sea receded, the clay sediments and salt minerals suspended in the Sea settled to the bottom and formed the current underlying and surficial soil structure that dominate significant portions of southeastern Ontario.

Leda clay is a highly unstable soil due to its highly variable internal structure. Consisting of non-uniformed size agglomerates (i.e., matrix of clay size particles) that are relatively porous, they are held together mainly through the electrostatic forces of the clay size particles and saline pore water (Bloom, 1978). Over time, as the soluble salts are removed from the clay structure through leaching, the relative stability of the soil structure becomes thixotropic or "sensitive" to disturbance.

When undisturbed, sensitive marine clays can appear as solid, stable soil structures. However, when these same soils are disturbed with excessive vibration, shock or become water saturated, the pore water moves, the weak framework of poorly arranged clay sediments collapses and the soil structure changes from a solid to a liquid. This change, depending on the level of disturbance, can occur within extremely short periods of time, sometimes in minutes.

Disturbance, in terms of vibrations or shocks, can be triggered by such thing as earthquakes, thunder, heavy traffic, blasting or spring break-up of ice in a river. As many of these triggering vibrations or shocks are not predictable the potential instability or movement of an area can occur with little or no warning. Similarly, disturbances caused by water saturation can be triggered by climatic or seasonal conditions (e.g., rainfall, snowmelt, ice break-up, etc.), by excessive loading on a slope (e.g., placement of fill or building) or by toe erosion where the area is exposed to flowing water. Other contributing factors may include changes in slope configuration, changes in piezometric pressures (i.e., ground water levels) within the slope, changes in drainage conditions and loss of vegetation.

The resultant **retrogressive failures** or **earthflows** are particularly dangerous as they can involve hectares rather than square metres of land. For example, in Saint-Jean-Vianney, Quebec, a progressive, or retrogressive, series of expanding slumps in 1971 engulfed numerous houses in a small village and resulted in the loss of 30 human lives. In Lemieux, Ontario, a series of retrogressive failures resulted in approximately 30 hectares (i.e., 75 acres) of land sliding into the South Nation River in 1993.

Three typical sources of sensitive marine clay information are available within Ontario. Geological maps, prepared by the Geological Survey of Canada, provide information on the types of surficial soils. Mapping generated by the Ontario Ministry of Natural Resources identifies areas where the sensitive marine clays associated with the Champlain Sea outcrop at the ground surface as well as providing an indication of the type of underlying soils where the clay deposits are thin. Lastly, local Conservation Authorities may have information pertinent to leda clays within their respective jurisdictions.

Provincial concerns related to sensitive marine clays are not limited to those areas that are located along rivers and streams. Concern extends to all areas of sensitive marine clays regardless of the presence or absence of a fluvial system.

Defining the "area of provincial interest" for sensitive marine clays should be based on one of two conditions:

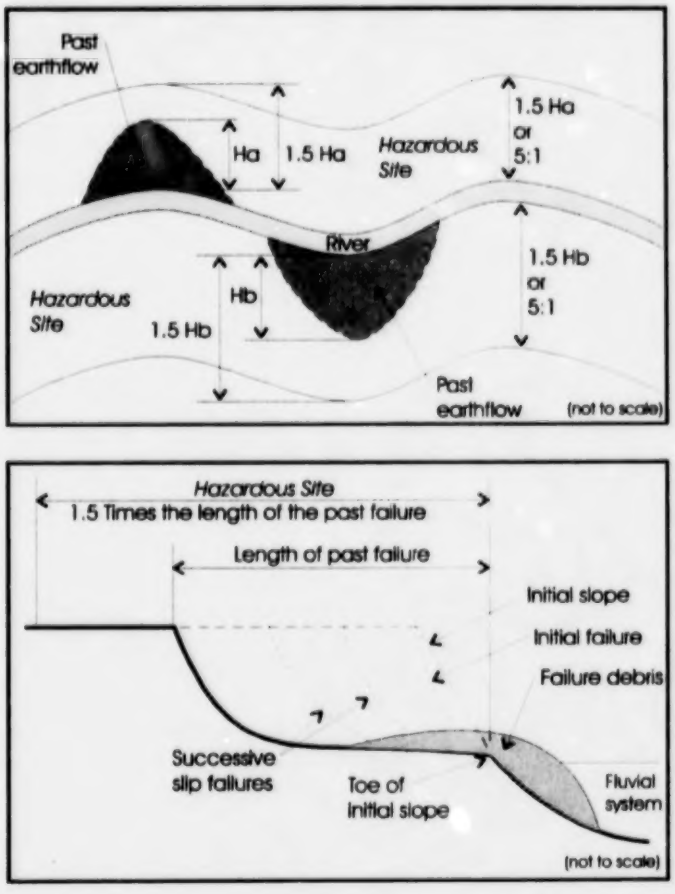
- there has been a retrogressive failure(s) of the slope in the past; or
- there is no current evidence suggesting that a retrogressive failure(s) has occurred.

Determination of these conditions can be made through aerial photographic interpretations, field mapping and measurement of slope parameters.

Where there is evidence of a retrogressive failure(s), the "area of provincial interest" or *hazardous site* should be defined by:

- **a horizontal allowance of 1.5 times the distance of the previous failure measured landward from the toe of the failure** (Figure 26) **OR as determined by a study using accepted scientific, geotechnical and engineering principles.**

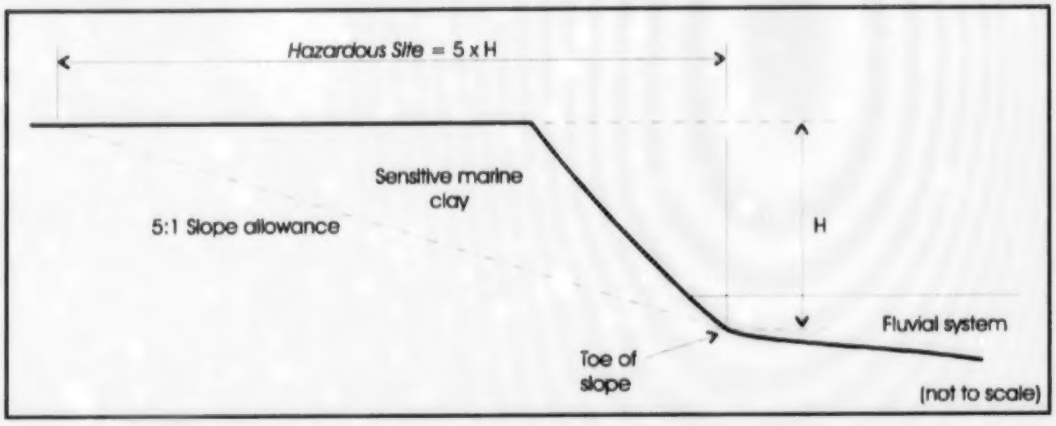
Figure 26: Horizontal Allowance in a Sensitive Marine Clay Where There is Evidence of Past Failure(s)



Where there is no evidence of a retrogressive failure(s), the "area of provincial interest" or *hazardous site* should be defined by:

- **a horizontal allowance of 5.0 times the height of the slope measured landward from the toe of the slope** (Figure 27) **OR as determined by a study using accepted scientific, geotechnical and engineering principles**.

Figure 27: Horizontal Allowance in a Sensitive Marine Clay Where There is No Evidence of Past Failure(s)



It should be clearly noted that the application of either of these approaches is intended to provide a level of protection against only the **first** occurrence of slope failure. Where a failure has occurred after either of these approaches has been applied, the allowances should be re-calculated and the new or revised allowance(s) applied.

In either case, a minimum factor of safety of 1.5 is recommended. Factor of safety is a measure of risk of failure or movement and is determined from an analysis of the ratio of the resistance of the movement of material (e.g., soil strength) as compared to the forces acting on the material (e.g., gravity, ground water levels, slope inclination, soil weight) that may cause movement.

Where municipalities and planning boards determine that the identified horizontal allowance is excessive or not sufficient enough, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using accepted scientific, geotechnical and engineering principles to determine the appropriate horizontal allowance. This flexibility may not be warranted or desired where a more precise definition of the *hazardous site* (i.e., leda clay) horizontal allowance is not necessary, where there is sufficient area within the development lot to site any proposed development outside of the *hazardous site*, where development pressure is low and alternative development sites exist, or where the staff, administrative and financial resources within the municipality may preclude the ability of the municipality to support such studies.

For those situations where a study, based on a minimum factor of safety of 1.5, is used to determine the *hazardous site* horizontal allowance, the study should be undertaken using "accepted scientific, geotechnical and engineering principles". Where studies using accepted scientific, geotechnical and engineering principles are approved by the municipality or planning boards, they should be applied only in the area studied.

For information on what is considered "accepted scientific, geotechnical and engineering principles" in the sense of what methodologies are considered appropriate for use in a given situation(s) and the appropriateness and applicability of study results, the report entitled *Geotechnical Slope Stability Study: Sensitive Marine Clays, Southeastern Ontario* (Golders 1988) and the *MNR Technical Guide for Hazardous Sites* (1996) should be consulted.

Some studies of *hazardous sites* (i.e., leda clays) have also been undertaken by local agencies. These allowances are generally unique to specific locations or areas. Where local studies have been undertaken using accepted scientific, geotechnical and engineering principles they may be used to determine the *hazardous site* for the area studied.

b) Unstable Soils: Organic Soils

Organic and peat soils are normally formed in an environment where the process of *humification* is occurring. Humification involves the process of transformation or decomposition of vegetative and/or organic materials into humus (i.e., dark brown to black organic matter similar to topsoil). The rate of humification is controlled by other conditions such as the level of saturation, the presence of inorganic materials, soil moisture content, temperature and the state of anaerobic or aerobic soil conditions (i.e., absence or presence of oxygen). The humification process of organic and peat soils also results in the release of various humic acids to the ground water system and in the creation of methane gas which is highly explosive.

The determination of whether a soil is considered to be organic is based on the percentage loss by weight of the soil when heated. If 5 to 80 percent of the weight is lost when heated, the soil is considered to be organic (Johnson 1995). By this definition, there is a wide array of soil types that can be considered to be organic.

Peat materials are the most commonly encountered type of organic soils next to topsoil. It is estimated that approximately 25 percent of Ontario's land area is covered by peat soils. Peat soils are defined as a *complex composition of inorganic minerals and organic materials, derived from leaves, plant remains and wood fragments, in varying stages of decomposition (i.e., humification).* If the peat soil is in a non-humified or slightly humified state, the soil is relatively fibrous. In a humified state, the peat soil is transformed into an amorphous (i.e., having no definite shape or form) mushy mass without any discernible structure (Johnson 1995). In addition, peat soils are easily eroded by surface water and/or ground water flow and are *highly compressive* (i.e., limited ability to support structures).

By the very nature of these materials, defining the "areas of provincial interest" is a site specific process. To develop a single "approach" applicable in all situations is impractical and inappropriate given that the size, extent and severity of potential hazards and risks (e.g., structure collapse, release of methane gas) are largely the result of localized and often unique conditions.

These types of soils are most likely to be found in and associated with the delineation of wetlands (Policies 2.3). As a result of the wetland evaluation exercises coordinated by the Ministry of Natural Resources, information on the location of organic and peat soils may be available through the various MNR field offices. In addition, surficial geology maps prepared by the Ministry of Northern Development and Mines and/or the Geologic Survey of Canada and the *MNR Technical Guide for Hazardous Sites* (1996) may provide information to assist in identifying areas where organic soils may be present and how to manage these soils when they are encountered.

c) Unstable Bedrock: Karst Formations

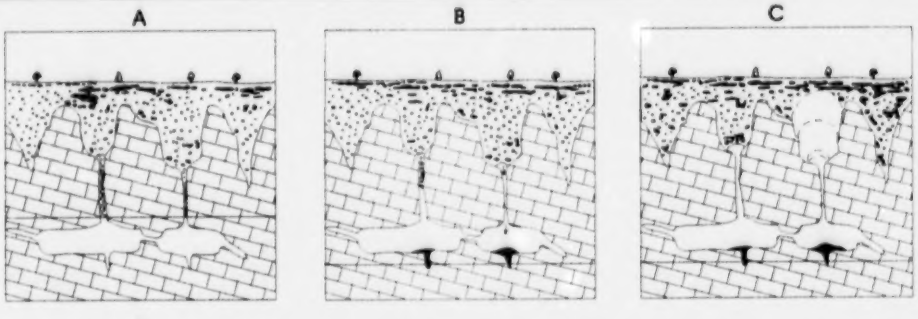
In Ontario, areas of unstable bedrock are usually associated with karst formations. By definition, karst is a geomorphological environment where water flowing over and through limestone and dolomite bedrock results in the creation of sinkholes, trenches and subsurface caverns.

Complex interactions between a number of variables combine to create karst formations. These include, but are not limited to:

- acidic concentrations of surface water, infiltrating water and ground water in relation to calcium carbonate and/or magnesium carbonate compositions of the bedrock (i.e., dissolution of the rock);
- proximity of the water table in relation to the bedrock (i.e., distance and depth that water will percolate through the bedrock from the surface to the ground water table);
- degree and number of bedrock fractures, fissures, joints and faults allowing water movement; and
- presence of impermeable layers either above or below the limestone/dolomite that will influence the flow patterns of water.

Like any geomorphological feature, karst formations can be quite variable in their character and "maturity" depending on the interaction of the above variables over time. For example, Figure 28 conceptually depicts the stages of landform development for karst formations. In general these stages are initiated by water flowing over, through and beneath an area of limestone or dolomite bedrock. The result is the creation of sinkholes, funnel shaped surface depressions with a hole in the centre, and a series of underground channels that are largely joint-guided. Over time, as surface water continues to funnel down through the sinkholes they become enlarged and caverns are created by the underground flow of water. With continued erosion and dissolution, the water table becomes lower and the ceilings or crowns of caverns, located above the flowing water table, become exposed. As the erosion and dissolution process continues to work on the crowns of caverns through percolation, a weakening occurs that may cause the collapse of the cavern.

Figure 28: Sink Hole Development in a Karst Environment



Progressive development of sinkhole over a cavernous limestone due to ground water withdrawal in South Africa (after Brink, 1979). A. The equilibrium situation before the lowering of the water table. B. The lowering of the water table. There is active subsurface erosion (piping into the open cave) as the slot is flushed out by a process of headward erosion. C. The progressive collapse of the roof of the vault, possibly temporarily arrested by a ferruginised pebble marker. D. The collapse of the last arch to produce a sinkhole surrounded by concentric tension cracks.

Karst formations, characterized by the presence of sinkholes, trenches and caverns of varying sizes and which may or may not be exposed at the surface, if undetected, pose concerns and difficulty for those involved in planning or development due to their relative instability and unpredictable nature. This is particularly true when undetected caverns and trenches fail or collapse and sinkholes appear after construction of a development. For example, the collapse and sudden appearance of sinkholes in a Florida karst formation resulted in the swallowing of cars, pavement and entire homes in 1981.

Defining the "area of provincial interest" or *hazardous sites* associated with karst formations normally involves a site-specific process. To develop a single "approach" applicable in all situations is impractical and inappropriate given that the size, extent and severity of the hazard(s) and risk(s) are largely the result of localized and often unique conditions.

In areas of limestone or dolomite bedrock, the presence of disappearing streams and pockmarked topography (i.e., resulting from the collapse of sinkholes) are clear indicators of the presence of karst formations (Figure 29). For those areas in the initial stages of development, aerial photograph interpretation of 1:5 000 or 1:10 000 scale air photos (i.e., preferably infra-red) allow for a rapid assessment of whether a patterned or pockmarked drainage condition exists that could be indicative of a karst environment. Present information suggests that karst formations are predominately found in the Guelph/Rockwood/ Elora area of Wellington County and portions of eastern Ontario. Typical sources of information may include but are not limited to the MNR, the Ministry of Northern Development and Mines, local spelunker groups and the *MNR Technical Guide for Hazardous Sites* (1996).

Figure 29: Stages of Karst Landform Development

A. Pre-existing stream flow pattern showing classic developmentof sinkholes and ephemeral (disappearing) streams.
C. Fully developed Karst system but with major stream channels cut down to underlying impermeable stratum.
B. Mature Karst development, including typical connected cave systems.
D. Relict Karstic knolls and outliers remain in re-established normal drainage system.

4.1.4 Linkages Between Natural Hazards (Policy 3.1)

Policies addressing natural hazards can in some situations overlap. This is often the case where rivers empty into a lake or shoreline area. Determination of which policy supersedes the other is determined by which hazards have the greater or controlling impact on the subject area.

In Figure 30 for example, the factors influencing the severity of flooding for a development site (e.g., at cross section B-B'), located on a river emptying into the Great Lakes, is controlled by lake-induced factors (e.g., wave action, setup). In this case, the approach used to determine the flood susceptible portion of the site, or the area of provincial interest, is defined by the application of the *flooding hazard* limit for the *Great Lakes - St. Lawrence River System* (i.e., Policy 3.1.1 (a)). Further upstream (e.g., at cross section A-A'), flood susceptibility is directly influenced by riverine related flooding impacts and as such, is defined by the application of the *flooding hazard* limit for *river and stream systems* (i.e., *flood plain*, Policy 3.1.1(b)).

In the example provided, consideration has only been given to matters related to flooding. In determining the potential for site development, all hazards having an influence on the "area of provincial interest" or *hazardous lands* should be evaluated and addressed.

For instance, in the example provided above, adherence to the *Public Health and Safety Policies* (i.e., Policies 3.1, *Provincial Policy Statement*) would require that all natural hazards impacting on the area be defined. This would necessitate the identification of not only the *flooding hazards* but also the *erosion hazards and dynamic beach hazards* for the shoreline of the *Great Lakes - St. Lawrence River System* and the *erosion hazards* for the *river and stream system*, where applicable, to properly define the *hazardous lands* (see Table 1).

Policies addressing natural hazards also play an integral role in determining the structure, composition and function of the ecosystem. As such, the linkages between natural hazard policies and those of other resource interests such as fish habitat, natural heritage, water quality and quantity, wetlands and others should also be recognized.

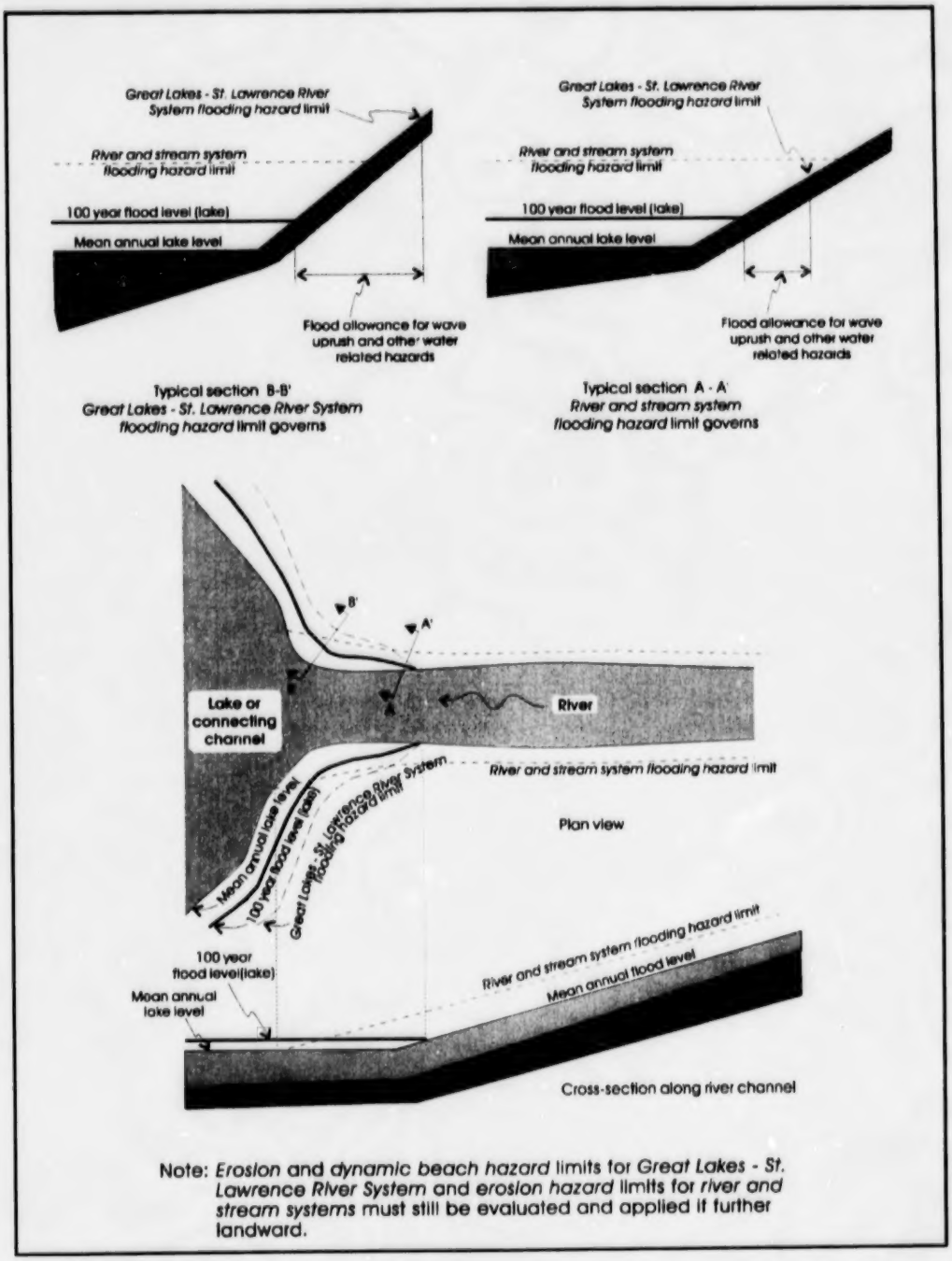
Frequently, there is an assumption that the definition and delineation of the different policies will consistently follow a set pattern along riverine or shoreline environments regardless of local conditions. This is rarely the case. Depending on the severity of the natural hazards and/or the significance or area of provincial interest for other natural resource-based policies, the areas defined by each policy may differ from one location to another. Typical variations on the delineation of natural hazard and other natural resource-based policies are provided in a series of riverine and shoreline environments outlined in Figure 31.

4.2 Development Within *Hazardous Lands* and *Hazardous Sites* (Policy 3.1.3)

The first premise of the policies governing natural hazards (i.e., Policy 3.1: *Public Health and Safety*) is that *development* and *site alteration* should be directed to locations outside of the areas of provincial interest to minimize risks to life and property damage (e.g., outside of the *hazardous lands* adjacent to the *Great Lakes - St. Lawrence River System*, *large inland lakes*, and *river and stream systems*, and *hazardous sites*).

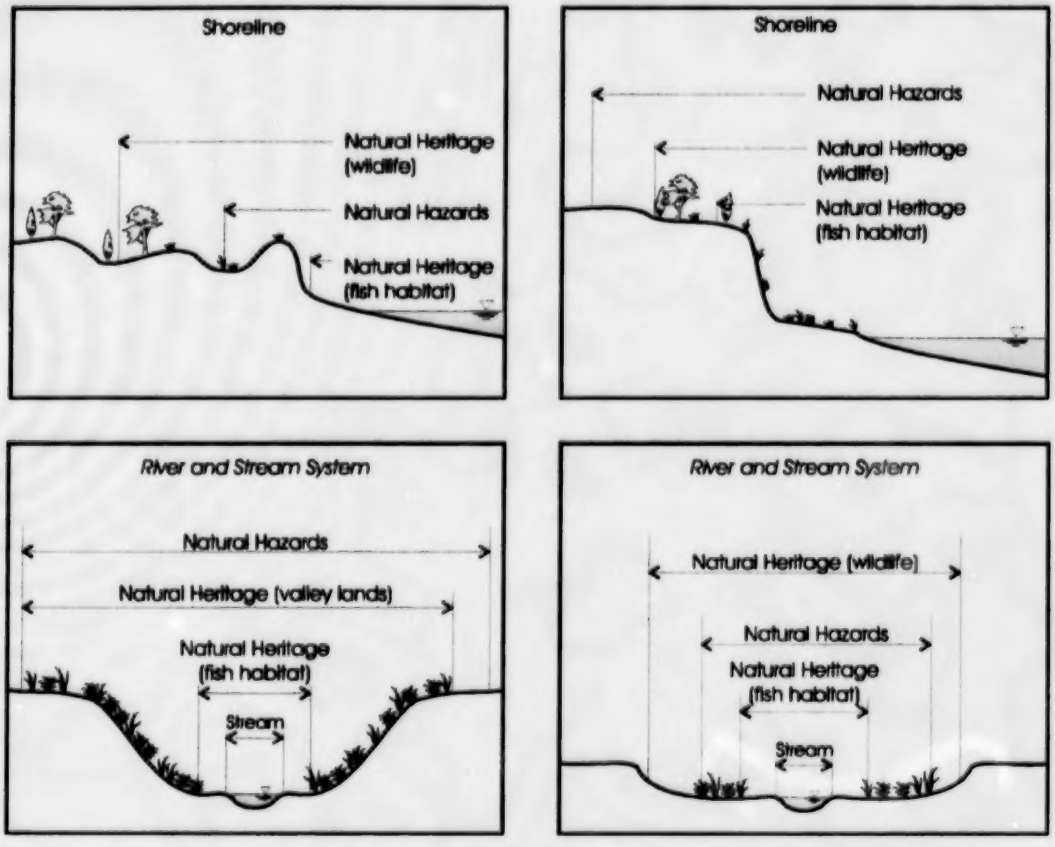
There may, however, be some unique, local situations where it may be possible to safely locate development within the least hazardous portions of the areas of provincial interest (e.g., within the *flood fringe* of *river and stream systems*). Although a brief synopsis of the matters to be addressed for development to be considered within *hazardous lands* and *hazardous sites* was provided in Section 2.0, a more in-depth discussion of the technical aspects of fully addressing these matters (Policy 3.1.1) is provided in Sections 4.2.2 to 4.2.5 of this Training Manual.

Figure 30: Overlap of Provincial Policies Addressing Natural Hazards


Great Lakes - St. Lawrence River System flooding hazard limit
River and stream system flooding hazard limit
100 year flood level (lake)
Mean annual lake level
Flood allowance for wave uprush and other water related hazards
Typical section B-B'
Great Lakes - St. Lawrence River System flooding hazard limit governs
Great Lakes - St. Lawrence River System flooding hazard limit
River and stream system flooding hazard limit
100 year flood level (lake)
Mean annual lake level
Flood allowance for wave uprush and other water related hazards
Typical section A - A'
River and stream system flooding hazard limit governs
B'
A'
Lake or connecting channel
River
River and stream system flooding hazard limit
Plan view
Mean annual lake level
100 year flood level (lake)
Great Lakes - St. Lawrence River System flooding hazard limit
100 year flood level(lake)
Mean annual lake level
River and stream system flooding hazard limit
Mean annual flood level
Cross-section along river channel

Note: *Erosion* and *dynamic beach hazard* limits for *Great Lakes - St. Lawrence River System* and *erosion hazard* limits for *river and stream systems* must still be evaluated and applied if further landward.

Figure 31: Overlap of Natural Hazard Policies With Other Resource Policy Interests



For those situations where *development* and *site alteration* may be considered within the least hazardous portions of the *hazardous lands* and/or *hazardous sites*, care should be taken to ensure that the interests and intent of other provincial policies are not compromised (e.g., natural heritage, fish habitat, wetlands, water quality and quantity, etc., which may not permit development).

Although there is the flexibility for municipalities and planning boards to consider *development* and *site alteration* within the least hazardous portions of the areas of provincial interest, there are certain situations where due to the unacceptable threats to life and property *development* and *site alteration* should not be permitted (Policy 3.1.2).

4.2.1 Portions of *Hazardous Lands* Where Development Should Not Be Permitted (Policy 3.1.2)

Although there may be situations where the natural hazards may be addressed in an environmentally sound manner such that *development* and *site alteration* may safely be located or take place within *hazardous lands* and *hazardous sites*, there are some areas where the risks to public health and safety are considered to be too high and *development* and *site alteration* should not be permitted.

In accordance with Policy 3.1.2, these areas include:

a) defined portions of the dynamic beach;

b) defined portions of the one hundred year flood level along connecting channels (the St. Mary's, St. Clair, Detroit, Niagara and St. Lawrence Rivers); and

c) a floodway (except in those exceptional situations where a Special Policy Area has been approved).

Given the unacceptably high risks to life and property associated with each of these areas, care should be taken to ensure that each of these areas are properly delineated and identified and that any and all implementing municipal planning tools or mechanisms clearly identify those areas wherein *development* and *site alteration* would not permitted.

a) *Defined Portions of the Dynamic Beach* (Policy 3.1.2 (a))

Defined portions of the dynamic beach (Policy 3.1.2 (a)) are those portions of the *dynamic beach* which are highly unstable and/or critical to the natural protection and maintenance of the first main foredune feature and/or beach profile where the impacts of flooding, wave action, and wind are greatest and as such, poses an unacceptable risk to life and property. This applies only to *dynamic beaches,* and not all beaches, of the *Great Lakes - St. Lawrence River System* and *large inland lakes.*

In determining the critical or "defined portions of a dynamic beach", various factors should be considered including, but not limited to:

- physical characteristics of the shoreline;
- each individual component of the *flooding hazard* (i.e., water levels, wave uprush, other water related hazards);
- duration and frequency of flooding;
- pre-development/post-development flood conditions/impacts;
- date and reliability of the flood information;
- availability, accuracy, applicability of existing engineering studies;
- dynamic nature and range of the shoreline sediments, profile and planform;
- sediment/material (e.g., type, size, depth, width, composition, etc.);
- exposure to wave action;
- nearshore/offshore bathymetry;
- orientation of prevailing winds relative to the shoreline alignment, exposure, etc.;
- aeolian forces (e.g., magnitude, duration, etc.); and
- influence of vegetation in stabilizing the dynamic beach.

Caution should be exercised in defining these areas. While development in such areas could adequately be floodproofed or the "hazards" potentially addressed through the use of protection works, past experience throughout the Province has repeatedly demonstrated that such decisions result in the creation of new hazards, the aggravation of existing hazards on updrift/downdrift properties, adverse environmental impacts, and ever increasing maintenance and replacement costs.

Past experience has also demonstrated that beach and dune formations left unaltered by humans, often naturally protect inland shoreline developments from the destructive impacts of shoreline flooding and erosion. For example, where *development* and *site alteration* have been directed to locations inland of

beach or dune features (i.e., landward of the first main foredune), these features often naturally prevent flood waters from reaching inland areas and absorb the erosive impacts and forces of wave action. Where left unaltered, as water levels recede these same beach and dune features naturally rebuild to once again provide protection to inland shoreline developments.

b) *Defined Portions of the 100 Year Flood Level Along Connecting Channels* (Policy 3.1.2 (b))

Policy 3.1.2 (b) applies only to the connecting channels of the *Great Lakes - St. Lawrence River System.*

Where development is being proposed along the connecting channels, municipalities and planning boards should give careful consideration to the potential impacts of such developments. Past experience has demonstrated that many areas of existing shoreline development are currently exposed to varying degrees of flood threat or risk. As such, the placement of additional development may result in an unacceptable increase in flood flows and associated increases in risks of property damage to existing and proposed developments, unacceptable impacts to other resource interests (e.g., aquatic, wildlife, etc.) and potentially unacceptable impacts or risks to properties located in other jurisdictions (e.g., United States). Given that regulatory agencies on the United States side of the connecting channels are opposed to any increases in the 100 year flood level, they should be consulted should any development proposal posing any potential increase in flood levels be contemplated.

In recognition of these obligations and concerns, the provincial policy states that within the *defined portions of the 100 year flood level along connecting channels* of the *Great Lakes - St. Lawrence River System* (e.g., those areas which are critical to the conveyance of the flow associated with the 100 year flood level), *development* and *site alteration* should not be permitted (i.e., Policy 3.1.2 (b)).

In determining the critical or "*defined portions of the 100 year flood level*" along the connecting channels of the *Great Lakes - St. Lawrence River System*, various factors should be considered including, but not limited to:

- physical characteristics of the connecting channel;
- influence and impacts associated with each individual component of the *flooding hazard* (i.e., water levels, wave uprush, other water related hazards);
- duration and frequency of flooding;
- pre-development/post-development flood conditions/impacts;
- date of the flood information;
- reliability of the flood information;
- availability, accuracy, applicability of existing engineering studies;
- assurance that long-term maintenance will be provided; and
- long-term maintenance costs where flood mitigation measures are proposed.

Caution should be exercised in designating chronic flood problem areas along the connecting channels as non-critical. While development in such areas could adequately be floodproofed, maintenance and upkeep would continuously be required to ensure floodproofing measures and local services remain effective.

In low-lying areas bordering the connecting channels, decisions related to the siting of development should be cognizant of the potential problems low-lying developments may pose. For these developments, it is often difficult and expensive to provide the necessary services to serve the development (e.g., water mains, sewers, drainage works). For example, drainage systems should and are intended to provide protection against flooding, however, in low-lying shoreline areas it may be difficult to provide outlets above the 100 year flood level. In these situations, it may be necessary to provide pumping facilities which could in turn result in some additional and substantial expense to obtain, operate and maintain, as well as an additional risk, should they fail during a flooding situation.

In addition to the potential risks and impacts associated with flood waters on low-lying developments themselves (e.g., structurally), developments proposed within the 100 year flood level should also address the need of providing safe access to and from the development as well as from individual properties and buildings. Developments where access from the site during flood and/or erosion emergencies are made impassable due to flooding would not be considered acceptable and should not be approved.

For additional information on the issues to be addressed in the calculation and delineation of the *defined portions of the 100 year flood level along connecting channels*, the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996) should be consulted.

c) *Floodway* (Policy 3.1.2 (c))

Policy 3.1.2 (c) applies only to *river and stream systems*.

Within the Province, three concepts of *flood plain* management are applied including: **one zone concept, two zone concept,** and in a few exceptional situations, a **Special Policy Area concept** may be applied. Regardless of the *flood plain* concept applied, the overall intent of the policies governing public health and safety should be assured (i.e., minimizing risks to life and property).

Where defined, *development* and *site alteration* should not to be permitted within the *floodway* (Policy 3.1.2(c). By definition, the only exceptions are:

- uses which by their nature must be located within the *floodway;*
- flood and/or erosion control works;
- minor additions and/or non-structural, passive uses, where appropriate, which do not affect flood flows; and
- where a *Special Policy Area* (SPA) has been approved by the Ministers of Natural Resources and Municipal Affairs and Housing.

i) Defining the *Floodway*: One Zone Concept

By definition, the *floodway* refers to that portion of the *flood plain* where *development* and *site alteration* would cause a threat to public health and safety or property damage. In other words, it is that portion of the *flood plain* required for the safe passage of flood flow and/or that area where flood depths and/or velocities are considered to be such that they pose a potential threat to life and property damage.

The one zone concept is the preferred approach for the management of *flooding hazards* within *river and stream systems* as it provides the most cost effective means of minimizing potential threats to life and risks of property damage and social disruption (Figure 32). The one zone concept basically involves the delineation of the *flooding hazards* limit, or *flood plain*, based on the calculation of the governing flood level (i.e., storm-centred event (Hurricane Hazel, Timmins), 100 year flood, or observed flood event). With the calculation of this line or *flood plain* limit, all development within this area should be prohibited or restricted to those structures which by their nature are to be located within this area, flood/erosion control works, or where appropriate, minor additions or passive, non-structural uses which do not affect flood flows.

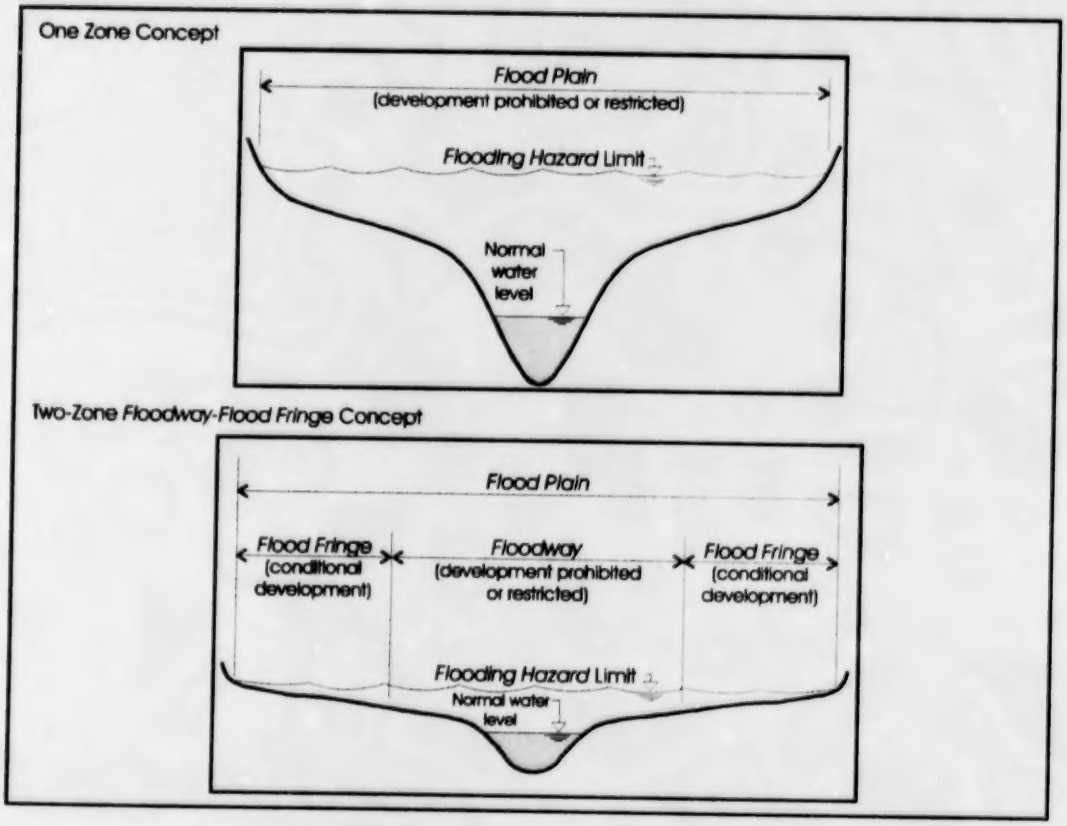
Where the one zone concept is applied, the entire *flood plain* (i.e., *flooding hazards* limit) defines the *floodway*. Where the two zone concept is applied, the inner portion of the *flood plain* is defined as the *floodway* (i.e., the outer portion is the *flood fringe*).

ii) Defining the *Floodway*: Two Zone Concept

The two zone concept relies on the identification of two areas (Figure 32):

- ***floodway*** — portion of the *flood plain* where development should not be permitted, the only exceptions being:
  - . uses which by their nature must be located with the *floodway*;
  - . flood and/or erosion control works; and
  - . minor additions and/or non-structural, passive uses, where appropriate, which do not affect flood flows.
- ***flood fringe*** — portion of the *flood plain* where development may be permitted subject to certain *established standards and procedures* being fulfilled (e.g., floodproofing).

Figure 32: One and Two Zone Concepts for *Flood Plain* Management



Under certain conditions, the flexibility to develop within the least hazardous portions of the *flood plain* may be considered by the municipalities and planning boards. The two zone concept provides the flexibility to first, define the governing flood level (i.e., *flooding hazards* limit), and secondly, to define those portions of the *flood plain* where development could be safely located subject to certain *established standards and procedures* being fulfilled (e.g., floodproofing, protection works, access). This flexibility is not intended to be applied throughout the entire watershed but should be limited to selective areas.

Under the two zone concept, no one standard, applied province-wide, exists for defining the limit of the *floodway*. Watershed conditions vary extensively throughout the Province and in some instances, vary substantially within individual watersheds. As a result, the determination of the more hazardous portions of the *flood plain* should be based on an analysis of local conditions. Data and technical criteria, many of which are similar to those collected and applied in determining the governing flood level, are evaluated as part of the analysis process leading to the determination of the *floodway*. The data and criteria may include, but are not limited to:

- critical flood depth and velocity that may pose a threat to life and property;
- extent of existing and proposed development and its location in the watershed (e.g., affect on flood water levels and flows);
- potential for upstream and/or downstream impacts if modification to and development in portions of the *flood plain* are permitted (i.e., affect on flood water levels and flows);
- physical characteristics of the watershed (e.g., steepness of slopes, instability of the banks, soil conditions, etc.); and
- feasibility of floodproofing.

In general, the two most important criteria for determination of the *floodway* and *flood fringe* are critical flood depth and velocity.

As stated earlier, there is not one single approach related to critical depth and velocity that can be applied province-wide in the determination and delineation of the *floodway* and *flood fringe*. There are, however, general approaches that have been developed for determining critical depths and velocities that will detrimentally influence people and structures within an area susceptible to flooding. These include:

- **depth (threat to life)**
  - in stagnant backwater areas (i.e., zero velocity), depths in excess of about 1 metre are sufficient to float young children, and depths above 1.4 metres are sufficient to float teenage children and many adults.

- **velocity (threat to life)**
  - in shallow areas, velocities in excess of 1.8 m/sec pose a threat to the stability of many individuals.

- **depth and velocity** (threat to life)
  - the hazards of depth and velocity are closely linked as they combine to effect instability through an upward buoyant force and a lateral force. A reasonable approximation of the combined hazard of depth and flood velocity can be made with the product of depth and velocity. A product of less than or equal to $0.4m^2/sec$ defines a low hazard provided the depth does not exceed 0.8m and the velocity does not exceed 1.7 m/sec.

- **vehicular access** (emergency access)
  - most automobiles will be halted by flood depths above 0.3-0.5m. A maximum flood velocity of 3m/sec would be permissible, providing that flood depths are less than 0.3m. A depth of 0.9-1.2m is the maximum depth for rapid access of large emergency vehicles.

- **structural integrity** (structures above ground)
  - a depth of 0.8m is the safe upper limit for the above ground/super structure of conventional brick, brick veneer, and certain types of concrete block buildings. The structural integrity of elevated structures is more a function of flood velocities (e.g., erosion of foundations, footings or fill) than depth. The maximum permissible velocity depends on soil type, vegetation cover and slope but ranges between 0.8-1.5m/sec.

- **fill** (stability)
  - in general, fill may become susceptible to erosion/instability at depths of 1.8-2.4m.

The above critical depth and velocity approaches or limits were derived from the minimum requirements normally applied when addressing floodproofing in Ontario. Since the distinction between the *floodway* and *flood fringe* is based on the premise that development within the *flood fringe* should only be considered where floodproofing measures are applied, then the use of the above approaches or limits should aid in the determination of these two zones.

iii) Special Policy Areas (SPA)

While the intent of the policies for *hazardous lands* adjacent to or within *river and stream systems* is clear (e.g., minimize risks to life and property), there may be unique and exceptional situations where flexibility to recognize continued community viability for those developments that may already exist within the *flood plain* may be warranted. It should be fully recognized that the use and applicability of this concept should be limited and applied only in a few, exceptional situations.

The *Special Policy Area (SPA) concept* should only be considered where the application of the two zone concept cannot reasonably be applied and all other requirements for *SPA* designation can be met.

Care should be taken when considering the option of a *Special Policy Area (SPA).* Designating an area as a *SPA* (i.e., accepting a lower standard of flood protection) does not remove the risks to life and property, it instead acknowledges that a greater risk to life and property exists and that these risks and liabilities require addressing and careful attention should development be considered.

Although a community, or a portion of a community, may qualify for *Special Policy Area* designation, not all of the *flood plain* lands may necessarily warrant being designated. The application of the *Special Policy Area* concept should be limited to those small areas which are essential for the continued viability of existing uses. The application of *SPA* status provides for additions, alterations and replacement of existing buildings and structures, and infilling (e.g., previously undeveloped lots within developed areas). It is intended that where applied, that these areas would be small in size.

A number of technical matters require analysis where the application of the *Special Policy Area concept* may be considered. These include, but are not limited to:

- appropriateness of other flood plain management measures (e.g., two zone concept, remedial measures);
- depth of flooding and velocity of flow, as affected by current and future development;
- frequency of flooding;
- feasibility of floodproofing measures;
- upstream and downstream effects (e.g., current and future);
- frequency of ice jams and other obstructions;
- use of berms and floodwalls; and
- potential reduction of the governing flood level (e.g., administrative procedure).

It should be noted that the acquisition of appropriate technical data does not necessarily lead to an automatic approval of the *two zone* or *Special Policy Area concept* within a given watershed location. In both of these situations, the adoption of the appropriate municipal planning mechanisms and the establishment of supporting administrative procedures determine the approval or denial of subsequent development applications. Regardless of which of these concepts is applied, municipalities need to ensure that the overall intent of the policy, minimizing the risks to life and property, is preserved.

It should also be noted that the procedure for securing a *Special Policy Area (SPA)* designation has not changed with the adoption of the *Provincial Policy Statement*. Approval from the Ministers of Natural Resources and Municipal Affairs and Housing remains as an essential step in securing a *SPA* designation. As such, early and continued involvement of the Ministry of Natural Resources in any process leading to a potential *SPA* designation is important.

For a more detailed discussion on the applicability, viability, feasibility and appropriateness of each of these concepts to a particular watershed location, and the factors to be considered and the administrative procedures related to securing *Special Policy Area* designation, the *MNR Technical Guide for River and Stream Systems* (1997) should be consulted.

4.2.2 Overall Policy Direction Related to Where Development May Be Permitted Within *Hazardous Lands* and *Hazardous Sites* (Policy 3.1.3)

In those portions of the *hazardous lands* and *hazardous sites* where *development* and *site alteration* may be considered, Policy 3.1.3 outlines the matters to be addressed. Where any one of the matters outlined in Policy 3.1.3 cannot be fulfilled, the Policy suggests that the proposed *development* and *site alteration* should not be permitted.

The matters to be addressed where *development* and *site alteration* (Policy 3.1.3) may be considered within the *hazardous lands* and *hazardous sites* include:

a) the hazards can be safely addressed and the development and site alteration is carried out in accordance with established standards and procedures;

b) new hazards are not created and existing hazards are not aggravated;

c) no adverse environmental impacts will result;

d) vehicles and people have a way of safely entering and exiting the area during times of flooding, erosion and other emergencies; and

e) the development does not include institutional uses or essential emergency services or the disposal, manufacture, treatment or storage of hazardous substances.

Although an overview of the overall intent and expectations related to each of these matters was provided in Section 2.0 of this Training Manual, Sections 4.2.3 to 4.2.5 provide a more in-depth discussion of applicable approaches and standards (e.g., *established standards and procedures*) and the interrelationships between them, additional considerations when dealing with *hazardous sites*, and finally, a suggested approach for balancing development interests and addressing hazards in an environmentally sound manner.

The inclusion of Policy 3.1.3 is intended to provide the flexibility to recognize local conditions. When applying this flexibility care should be taken to ensure that the magnitude or degree of risk(s) is clearly understood, that the potential or feasibility for *development* and *site alteration* to safely locate within certain portions of the *hazardous lands* and *hazardous sites* are sound, reasonable and can be implemented.

In combination with each other, Policy 3.1.3 (a) to (e) inclusive promote public safety and minimize risks to life, property damage, adverse environmental impacts and social disruption. Where all of these matters cannot be fulfilled, the Policy suggests that the *development* and *site alteration* should be directed to locations outside of the area of provincial interest (e.g., outside of the *hazardous lands* and *hazardous sites* designations).

Prior to considering *development* and/or *site alteration* within any identified *hazardous lands* and/or *hazardous sites*, it is recommended that Sections 4.2.3 to 4.2.5, in their entirety, be carefully reviewed and considered in any decision making process.

In addition, as stated previously, care should also be taken to ensure that the interests and intent of other policies (e.g., natural heritage, fish habitat, etc. which may not permit development) are not compromised.

4.2.3 Overview of *Established Standards and Procedures* (Policy 3.1.3 (a))

By definition, *established standards and procedures* (Policy 3.1.3 (a)), refers to those principles, methods and procedures which are used and applied in current water-related engineering practices, geotechnical practices and/or disciplines such as geology, geomorphology, botany and zoology. These include:

- **floodproofing**
- **protection works**
- **access**

a) *Floodproofing Standard*

Floodproofing is generally defined as a combination of structural changes and/or adjustments incorporated into the basic design and/or construction or alteration of individual buildings, structures or properties subject to flooding so as to reduce or eliminate flood damages. It is acknowledged that this term is somewhat misleading, in the sense that total protection from flood damage cannot always be assured. However, if applied effectively, floodproofing can play a significant role in comprehensive land use and resource management planning.

Floodproofing standards are applicable to flood susceptible portions of *hazardous lands* (i.e., within those areas defined by the *flooding hazards* limit) adjacent to the shorelines of the *Great Lakes - St. Lawrence River System* and *large inland lakes* and adjacent to and within *river and stream systems*. Details on the standards specific to each of these environments are outlined in the following subsections.

Where municipalities and planning boards have determined that *development* and *site alteration* could potentially be located within the least hazardous portion(s) of the *hazardous lands*, mechanisms should be incorporated into the planning process providing the flexibility to recognize and address the potential increased risk and/or threat to life and property and to ensure that the *development, site alterations* and required floodproofing measures are done in an environmentally sound manner.

i) ***Great Lakes - St. Lawrence River System* and *Large Inland Lakes***

In determining the level of floodproofing protection to be applied to shoreline developments, a differentiation should be made between those located on the Great Lakes or large inland lakes and those located on the connecting channels to recognize the differences in the level of shoreline exposure and risk to life and property. For example, shorelines of the Great Lakes and large inland lakes are exposed to greater risk of damage due to greater and more destructive wave action, wind setup, ice forces and storm surge, particularly during high lake levels, than properties located along the shorelines of the connecting channels.

For these reasons, the **established floodproofing standard** for shoreline developments should be:

- on the **Great Lakes** based on the cumulative elevation of:

100 year monthly mean lake level (e.g., long-term risk)	+	**100 year wind setup** (e.g., short-term risk of storm surge)	+	**flood allowance for wave uprush and other water related hazards** (e.g., short-term risk of the influence of storm surge/seiche)

- on the **connecting channels**, as a suggested minimum since wind and wave action are not usually significant factors given their relatively narrow width:

100 year flood level	+	**flood allowance for wave uprush and other water related hazards** (e.g., short-term risk of the influence of storm surge/seiche)

- on ***large inland lakes***, as a suggested minimum since wind and wave action are dependent on the numerous interdependent factors (e.g., size, orientation, prevailing winds, etc.):

100 year monthly mean lake level (e.g., long-term risk)	+	**100 year wind setup** (e.g., short-term risk of storm surge)	+	**flood allowance for wave uprush and other water related hazards** (e.g., short-term risk of the influence of storm surge/seiche)

NOTE: Where records for *large inland lakes* do not exist, the standard should be based on the highest known water level and wind setup.

ii) *River and Stream Systems* (*Flood Plains*)

The *established floodproofing standard* for development proposed within the *flood plains* of *river and stream systems* is that the development should be protected by acceptable floodproofing actions or measures, and that ingress/egress should be such that vehicular and pedestrian movement is not to be prevented during times of flooding. Clarification on what is considered "acceptable floodproofing measures" is outlined in the following subsection.

iii) Determining and Applying the Appropriate Floodproofing Measures

Although it may be technically feasible to incorporate floodproofing measures into structures exposed to any depth of shoreline or riverine flooding, or other water related hazards (e.g., shoreline wave action), in practice, the cost of floodproofing increases with depth. This may in fact prove to be the limiting factor in the construction of buildings where the potential of flood damage cannot be economically reduced or eliminated.

In addition, some floodproofing measures involve contingency items which need to be kept in a perfect state of readiness and be easily accessible at all times (e.g., pumps, check valves). As such, these items should undergo periodic inspections, testing and continual maintenance. Where these types of floodproofing measures are considered, they should be confirmed through a formal agreement (e.g., with the local conservation authority), to ensure the reliability and prompt implementation of these measures are assured during times of flood emergencies. The formal agreement should address matters such as, but not limited to, the respective roles, responsibilities and schedule of maintenance checks to be fulfilled by the local conservation authority, for example, and the municipality.

Regardless of the degree or magnitude of the shoreline or riverine flood hazards identified on-site, floodproofing measures should not be considered a remedy for all flooding problems. Other approaches may be more appropriate under certain conditions.

Floodproofing measures may be applicable with certain limitations and only after certain prerequisite information is developed and considered to verify or substantiate its feasibility and appropriateness. Since there are various types of floodproofing measures, selection of the most appropriate approach normally depends on the following conditions:

- nature of the development and adjoining property under consideration (e.g., existing structure or proposed new structure, type of land use, impact on neighbouring properties);
- physical characteristics of the area (e.g., shoreline, watercourse), in order to evaluate the potential for updrift and/or downdrift impacts (i.e., physical and biological) in shoreline areas and the potential for upstream and/or downstream impacts within riverine areas;
- characteristics of local flooding conditions (e.g., water levels only, or are these levels aggravated by wave uprush and other water related hazard(s) as in shoreline areas) and the applicable *floodproofing standard*, in order to evaluate the type or degree of floodproofing required and the requirements for access (i.e., ingress/egress); and
- cost-effectiveness of the floodproofing measure(s).

Within the Province of Ontario, there are essentially two basic approaches to floodproofing:

- **dry floodproofing**
  - the use of fill, columns, or design modifications to elevate openings in buildings or structures above the *floodproofing standard,* **OR**
  - the use of water tight doors, seals, berms/floodwalls to prevent water from entering openings below the *floodproofing standard*

- **wet floodproofing**
  - the use of materials, methods and design measures to maintain structural integrity and minimize damage due to flood water and other water related hazards
  - building or structures are designed to intentionally allow flood waters to enter

In addition, there are essentially two basic techniques to floodproofing:

- **active floodproofing**
  - floodproofing techniques which require some action prior to any impending flood in order to make the flood protection operational (e.g., closing of water tight doors, installation of waterproof protective coverings over windows)

- **passive floodproofing**
  - floodproofing techniques which are permanently in place and do not require advance warning and action in order to make the floodproofing and/or flood protection measure effective

In addition, land use considerations could also influence the type of floodproofing measures to be applied. Development can generally be grouped into three major categories:

- **multi-lot, large lot and large scale development**
  - creation of multiple lots, or large lot, medium to high density residential development, or other large scale developments.

- **residential or habitable infilling, redevelopment, replacement, major additions/alterations, minor additions/alterations** where:

  - **infilling** involves development on previously undeveloped lots, or the creation of a residential lot, generally between two existing developed lots of a similar size and which are situated on the same side of a road and are not more than 100 metres apart;

  - **redevelopment/intensification** involves an existing residential unit being removed from previously developed, serviced land and a new larger residential unit being erected in its place, or the creation of new residential units or accommodation in existing buildings on previously developed, serviced land;

  - **replacement** involves the removal of an existing structure and a new residential or habitable unit for the same use and of the same size or smaller being erected;

  - **major additions/alterations** involves construction which is equal to or exceeds 30% for erosion hazards, and/or 50% for flooding hazards, of the foundation area or market value of the existing structure or work; and

  - **minor additions/alterations** involves construction that is less than 30% for erosion hazards, and/or 50% for flooding hazards, of the foundation area or market value of the existing structure or work.

- **non-habitable buildings and structures** where:

  - **major structures** involves non-habitable buildings and structures that do no qualify as minor structures; and

  - **minor structures** involves non-habitable, moveable structures with no utilities and a maximum size of 14 square metres.

For these various development scenarios, different land use factors will influence the range or type of floodproofing measures which may be deemed appropriate. For example, the height of surrounding buildings will likely be a primary consideration in examining possible floodproofing measures for infilling, replacement buildings, and major additions/alterations. As a result, floodproofing through the use of fill may be deemed undesirable in certain situations. However, for a large, multi-lot subdivision, conformity with surrounding areas may not necessarily be as critical.

In keeping with the policy goal of minimizing risks and threats to life and property damage, certain floodproofing approaches may be less desirable for some land uses than others. For example, special consideration should be given to land uses such as residential where overnight accommodation exists. Wherever possible, floodproofing measures should be to the defined *floodproofing standard*, however, lower levels of protection may be considered appropriate where there is adequate rationale and justification (e.g., floodproofing requirements are lessened/altered with the installation of protection works). The Ontario Building Code also provides floodproofing and waterproofing requirements.

In conclusion, the following will serve to guide **floodproofing measures** in Ontario:

- in general, dry passive flood protection is the most desirable approach for all types of development;

- new multi-lot or large lot residential development and the habitable portions of any other new buildings should incorporate dry passive floodproofing measures. Wet floodproofing measures should not be considered acceptable;

- it is recognized that the proximity to water is a key consideration in the use and enjoyment of recreational facilities (e.g., marinas, campgrounds, boathouses, park buildings, etc). As such, dry passive floodproofing may not be achievable or practical in all instances but should, however, be implemented to the fullest extent possible;

- wet floodproofing may be considered appropriate for new development earmarked for non-residential/non-habitable use and for buildings accessory to residential/habitable uses (e.g., garages). Dry active floodproofing could also be considered appropriate where a minimum of six (6) hours flood warning is available;

- minor additions/alterations to an existing building should be the only type of development permitting floodproofing to less than the applicable *floodproofing standard*;

- minor additions/alterations should incorporate floodproofing measures to the extent and level possible, based on site-specific conditions. As a minimum, the addition/alteration should not be more flood vulnerable than the existing structure;

- infilling, replacement or major additions for residential/habitable use, should require dry passive floodproofing to the applicable *floodproofing standard*. However, where such a requirement impacts on or is significantly out of context with neighbouring properties, other flood reduction approaches, such as dry active or wet floodproofing measures may be considered. Any acceptable floodproofing approach could be considered appropriate for infilling, replacement or major additions/alterations for non-residential/non-habitable use; and

- access (ingress/egress), as a minimum, should be considered "safe" for all new buildings, such that flood depths and associated wave action do not hinder safe pedestrian and vehicular movement during times of flooding.

With increases in flood levels and the impacts associated with other water related hazards (e.g., wave action, wave spray, ice, etc.), design considerations for floodproofing buildings and structures generally become more complex and costly. In addition, increasing flood levels and associated hazards pose greater risks to loss of life and property damage. As different buildings and structures can withstand flooding, other water related hazards and related loadings better than others, it is suggested that a professional engineer or architect skilled in floodproofing measures carry out the required evaluation and design stages, to ensure that these factors have been critically assessed and duly recognized in the selection of the floodproofing measure(s) deemed appropriate for the given location.

For information on those factors to be addressed when considering development and associated floodproofing requirements in an environmentally sound manner, the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996), the *MNR Technical Guide for Large Inland Lakes* (1996), and the *MNR Technical Guide for River and Stream Systems* (1997) should be consulted.

b) *Protection Works Standard*

Protection works are generally defined as a combination of non-structural or structural works or landform modifications constructed or designed to address the impacts of all natural hazards including *flooding hazards*, including wave action on shorelines, to arrest *erosion hazards* or the landward retreat of eroding shorelines and *river and stream system* banks, and/or to address *dynamic beach hazards*. It is acknowledged that this term is somewhat misleading, in the sense that total protection from natural hazards damage cannot always be assured (e.g., structural integrity cannot be assured in perpetuity; the design, size, etc. cannot fully address the full magnitude of the flooding and/or erosion forces). However, if applied effectively, protection works, when done in an environmentally sound manner, can play a significant role in comprehensive land use and resource management planning.

In general, where actions intended to address natural hazards involve the installation of protection works, emphasis should be placed on non-structural or soil bio-engineering approaches. Protection works using structural approaches may be considered appropriate where such actions are required to protect existing developments that are at high risk and where non-structural or soil bio-engineering solutions are not feasible provided the environmental impacts have been appropriately addressed and incorporated into the design of the protection works.

Regardless of the type of protection works selected there are two crucial factors often ignored when dealing with protection works:

- the long-term functionality; and
- the level of protection provided by the selected protection works.

Addressing these factors is normally achieved and dependent on a commitment to regular inspection and maintenance and/or repair or replacement in the event of failure. As such, where protection works are being installed:

- **design and installation of the protection works should be such that access to the protection works by heavy machinery for regular maintenance purposes and/or to repair the protection works should failure occur should not prevented.**

This involves care in the design and siting of buildings and structures on the subject property (e.g., buildings with narrow side yards could potentially restrict landside access to a failed protection works).

Although ongoing research is resulting in a better understanding of the physical forces and their interaction with protection works, continued research is needed to improve the understanding of the physical processes in the immediate vicinity of the protection works to better describe and predict their performance. For example, in the case of shoreline developments, many shoreline processes and wave-structure interactions can be approximated for engineering design purposes by equations, through physical model studies and through field observations. However, unlike building design which has established and widely accepted standards which are outlined in the Ontario Building Code or in the National Building Code, shoreline structural design has no nationally or provincially accepted procedures and criteria.

This lack of well-defined criteria for all natural hazards (i.e., riverine, shoreline, etc.) makes it difficult to measure reliably and accurately the suitability and long-term integrity of various protection works. Despite this lack of established and widely endorsed sets of standards, there are some widely accepted evaluation criteria which should be applied in the decision-making process.

These include but are not limited to:

- project life;
- design life;
- level of risk;
- functional performance;
- structural integrity;
- construction materials and methods;
- structure maintenance and replacement (e.g., life-cycle costs);
- impacts to surrounding properties (e.g., updrift/downdrift; upstream/downstream);
- environmental soundness; and
- aesthetics and recreational value.

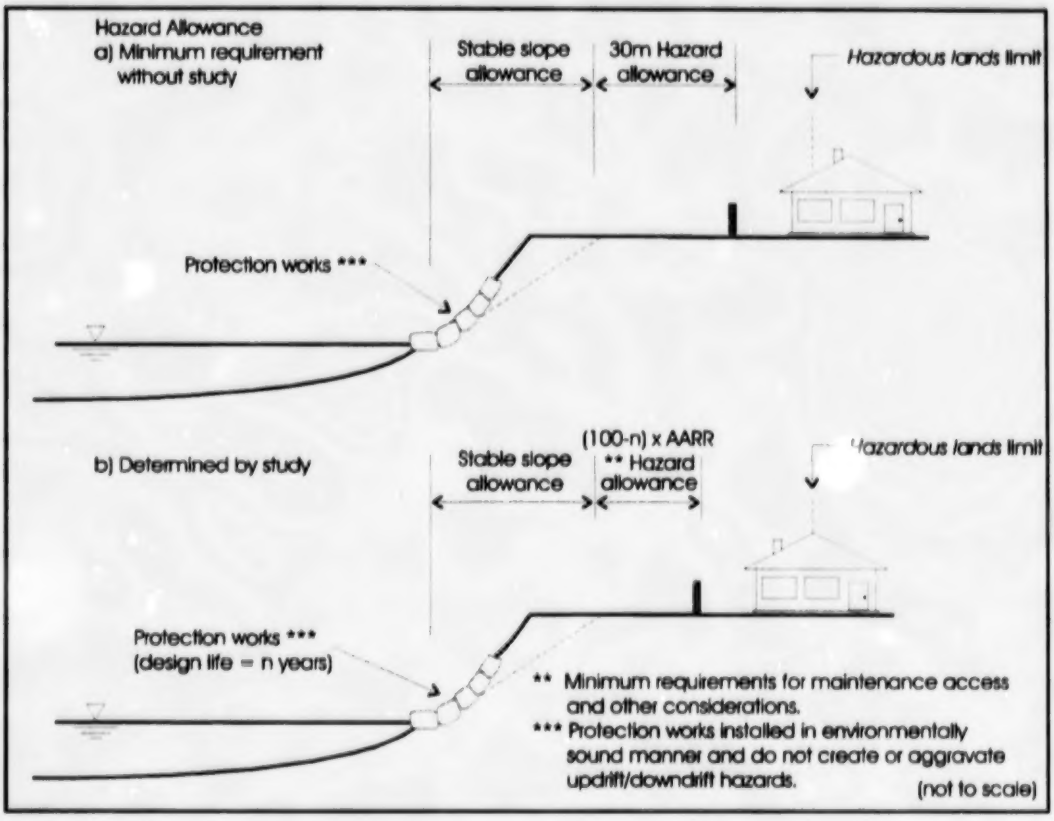
The relative importance of each of these criteria and the rigour with which they are evaluated may vary with each project. As a standard evaluation procedure, care should be taken to consider the type and size of the project, the sensitivity of the location and the potential threats to life and property in determining the level of study that goes into the design and selection process. The objective is to identify, evaluate and document the proposed development activity, the physical processes and characteristics, the proposed treatment, the *flooding, erosion* and *dynamic beach hazards*, and the potential impacts.

i) *Great Lakes - St. Lawrence River System*

In addressing the natural hazards (i.e., *flooding, erosion*, and/or *dynamic beach hazards*) along the shorelines of the *Great Lakes - St. Lawrence River System*, when development is being considered within the least hazardous portions of the *hazardous lands*, the following *protection works standard* should be applied (Figure 33):

protection works (non-structural, structural works)	+	**allowance for stable slope** 3:1 (h:v) **OR** as determined by a study using accepted geotechnical principles	+	**30 metre hazard allowance** **OR** as determined by a study using accepted scientific and engineering principles

Figure 33: ***Protection Works Standard - Great Lakes - St. Lawrence River System***


Hazard Allowance
a) Minimum requirement without study
Stable slope allowance
30m Hazard allowance
Hazardous lands limit
Protection works ***
b) Determined by study
(100-n) x AARR
Stable slope allowance
** Hazard allowance
Hazardous lands limit
Protection works ***
(design life = n years)
** Minimum requirements for maintenance access and other considerations.
*** Protection works installed in environmentally sound manner and do not create or aggravate updrift/downdrift hazards.
(not to scale)

Where the *protection works standard* is considered to be too excessive or insufficient to address the severity of the shoreline natural hazards impacting on a particular site, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using "accepted geotechnical principles" to determine the stable slope allowance and "accepted scientific and engineering principles" to determine the appropriate hazard allowance.

Where the municipality or planning board approves the studies using accepted geotechnical principles to determine the stable slope allowance and the studies using accepted scientific and engineering principles to determine the hazard allowance, the *protection works standard* should then consist of the protection works plus the approved stable slope allowance plus the approved hazard allowance and should be applied only to the shoreline area studied.

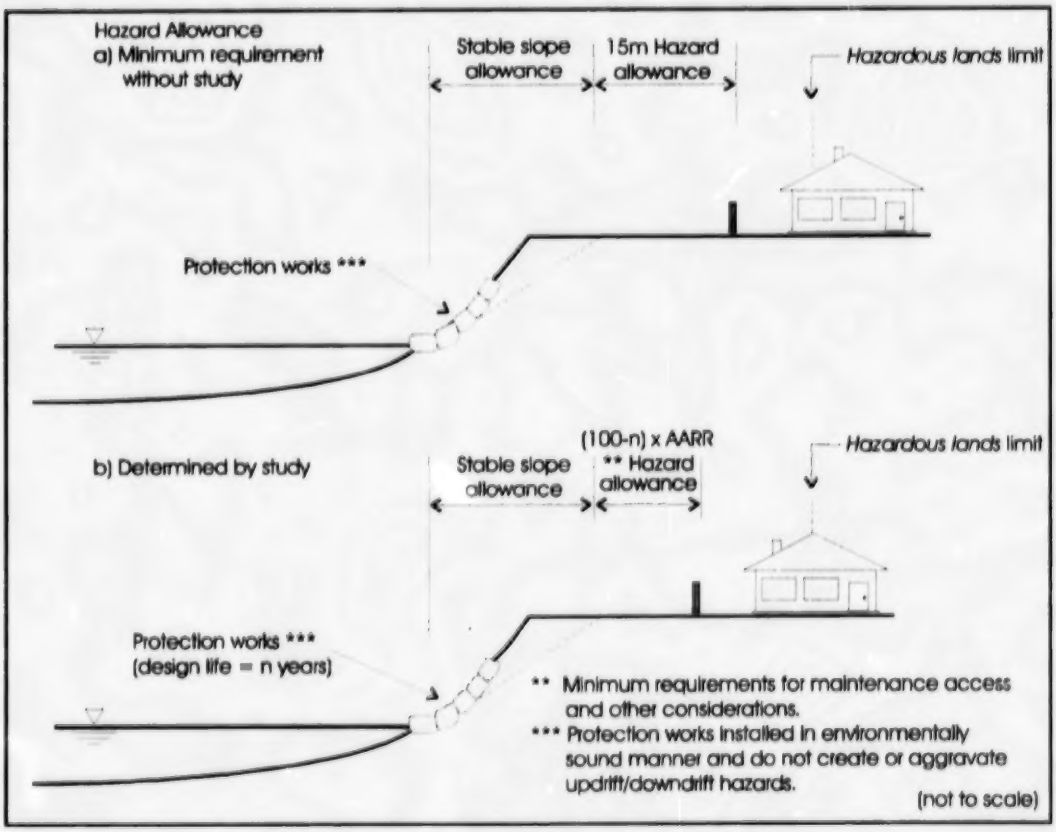
For additional information on what is considered "accepted geotechnical principles" and "accepted scientific and engineering principles" in the sense of what methodologies are considered appropriate for use in a given situation(s), the appropriateness and applicability of study results, and of suggested approaches to design and install protection works in an environmentally sound manner, the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996) should be consulted.

ii) *Large Inland Lakes*

In addressing the natural hazards (i.e., *flooding, erosion* and/or *dynamic beach hazards*) along the shorelines of *large inland lakes*, when considering development within the least hazardous portions of the *hazardous lands*, the following *protection works standard* should be applied (Figure 34):

protection works (non-structural, structural works)	+	**allowance for stable slope** 3:1 (h:v) **OR** as determined by a study using accepted geotechnical principles	+	**15 metre hazard allowance** **OR** as determined by a study using accepted scientific and engineering principles

Figure 34: *Protection Works Standard - Large Inland Lakes*


Hazard Allowance
a) Minimum requirement without study
Stable slope allowance
15m Hazard allowance
Hazardous lands limit
Protection works ***
b) Determined by study
(100-n) x AARR
** Hazard allowance
Stable slope allowance
Hazardous lands limit
Protection works ***
(design life = n years)
** Minimum requirements for maintenance access and other considerations.
*** Protection works installed in environmentally sound manner and do not create or aggravate updrift/downdrift hazards.
(not to scale)

Where the *protection works standard* is considered to be too excessive or insufficient to address the severity of the shoreline natural hazards impacting on a particular site, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using "accepted geotechnical principles" to determine the stable slope allowance and "accepted scientific and engineering principles" to determine the appropriate hazard allowance.

Where the municipality or planning board approves the studies using accepted geotechnical principles to determine the stable slope allowance and the studies using accepted scientific and engineering principles to determine the hazard allowance, the *protection works standard* should then consist of the protection works plus the approved stable slope allowance plus the approved hazard allowance and should be applied only to the shoreline area studied.

For additional information on what is considered "accepted geotechnical principles" and "accepted scientific and engineering principles" in the sense of what methodologies are considered appropriate for use in a given situation(s), the appropriateness and applicability of study results, and suggested approaches to design and install protection works in an environmentally sound manner, the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996) should be consulted.

iii) *River and Stream Systems*

The installation of protection works within *river and stream systems* are intended to address natural hazards (i.e., *flooding* and/or *erosion hazards*). For the purposes of clarification, guidance on matters related to protection works within *river and stream systems* will be discussed in terms of: first, the provision of major flood control, and secondly, the standards to be applied to address localized flooding and erosion impacts.

- **Major Flood Protection Works**

In certain situations, major or large flood protection works have and will be carried out to address flooding problems. Works such as large-scale channelization, dams and dykes are intended to address existing flooding problems in total or in part. They should not intended to enhance the developable nature of the *flood plain*, although it is recognized that some re-development and infilling may be more readily achieved with major flood protection works in place.

The potential exists for any major flood protection work to be overtopped or fail under extreme flood conditions. However, proper design, construction, maintenance and operation should reduce such a potential.

If a channelization works were to fail, the major concern would be erosion. By comparison, if a dam or dyke, which are often designed to hold back significant amounts of water, were to fail the resulting impacts would be far greater. As such, where development may be considered behind dykes or downstream of dams, the following matters should be taken into account.

Where a **dyke** has been properly designed and constructed to the *flooding hazard* limit (i.e., level), and a suitable maintenance program in place, the area behind the dyke may be considered as *flood fringe*. As such, development located within the flood fringe should be required to be floodproofed to the *flooding hazard* limit (i.e., level). The *floodway* would be considered to be contained within the dyke area. If development cannot be floodproofed to the *flooding hazard* limit (i.e., level), then *Special Policy Area* status may be requested, subject to the appropriate requirements.

As a precaution, certain areas immediately behind a dyke may be considered too hazardous for certain types of uses, if failure of the dyke was ever to occur. Also, the area immediately behind the dyke may be required for maintenance purposes.

Various types and designs of flood protection works or control **dams** can be found throughout Ontario. Some are passive in that there is no means of controlling discharge (e.g., earthen dams), some have basic means of control such a stop logs, and others have electrically operated flood gates with full-time operators. Some dams are considered multi-purpose providing recreational use, irrigation or flow augmentation, in addition to flood control. Some are designed to flood criteria and others to higher levels (e.g., maximum probable).

The extent to which the operation of a dam is taken into account in the calculation of downstream flood lines, the extent to which development may or may not be permitted in downstream areas, and the extent to which floodproofing for development may or may not be required, are all dependent on the type and design standard of the dam and local watershed conditions.

It should be remembered that the function of a flood control dam is to hold back upstream flood waters. When a flood occurs below a dam, the dam is of limited or no use. Whatever the type or design of dam, these structures should not be considered as a floodproofing option. The approaches and issues specific to floodproofing (outlined in Section 4.2.3) should be applied to any proposed development. In addition, the local Conservation Authority or the Ministry of Natural Resources should be consulted as to their treatment of flood control dams within their overall approach to *flood plain* management.

- ***Protection Works Standard***

In addressing the natural hazards (i.e., *flooding* and/or *erosion hazards*, including unstable slopes), so as to considered development within the least hazardous portions of the *hazardous lands* for *river and stream systems*, the following *protection works standards* should be applied:

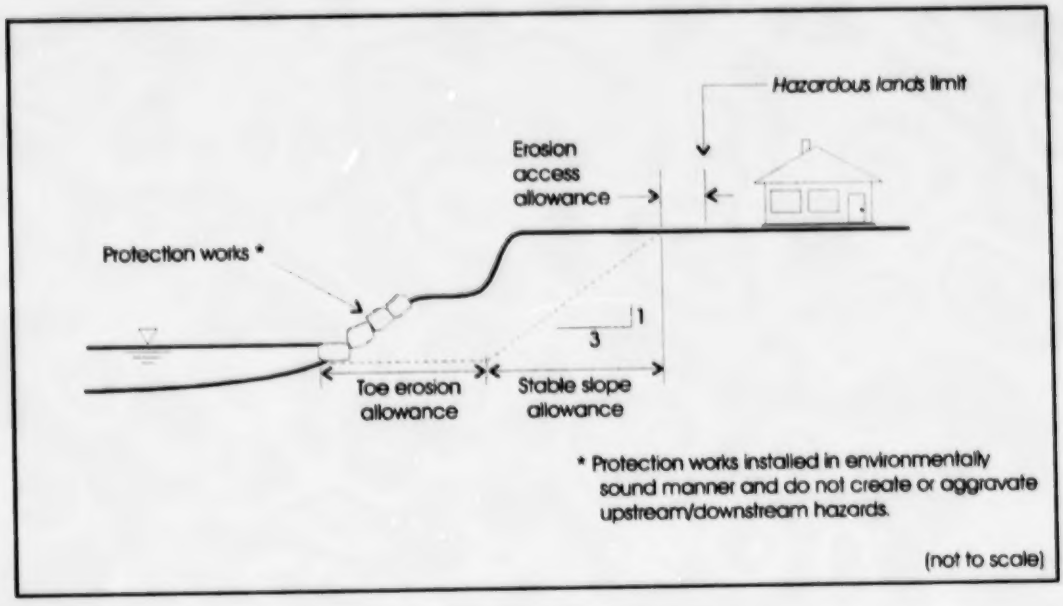
- for **confined systems** and **terrain-dependent systems** (consisting of cohesive materials)(see Figure 35)

protection works (non-structural, structural)	+	**toe erosion allowance*** (from Table 2 OR 100 times the average annual recession rate of the toe) **OR** a study using accepted geotechnical and engineering principles	+	**allowance for stable slope** 3:1 (h:v) **OR** as determined by a study using accepted geotechnical principles	+	**erosion access allowance** 6 metres **OR** as determined by a study using accepted scientific, geotechnical and engineering principles

* Note: . *where the soil type is not known, Table 2 recommends the use of a 15 m toe erosion allowance; and*

. *when using average annual recession rates to determine the toe erosion allowance a minimum of 25 years of reliable information is recommended.*

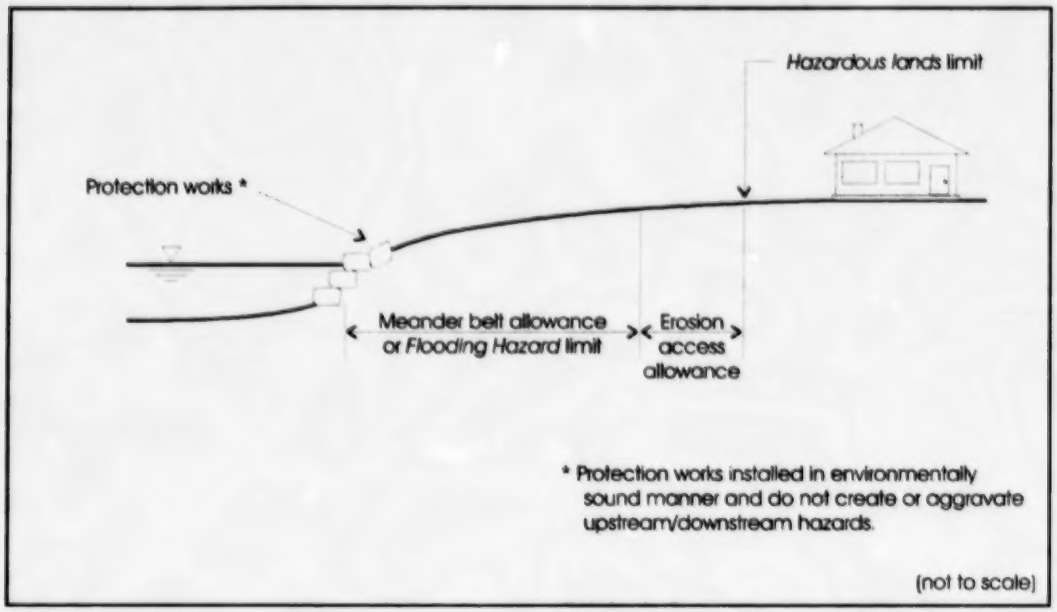
Figure 35: *Protection Works Standard:* Confined or Terrain-Dependent with Cohesive Material


Hazardous lands limit
Erosion access allowance
Protection works *
1
3
Toe erosion allowance
Stable slope allowance
* Protection works installed in environmentally sound manner and do not create or aggravate upstream/downstream hazards.
(not to scale)

- for **unconfined systems** and **terrain-dependent systems** (consisting of cohesionless materials)(see Figure 36)

protection works (non-structural, structural works)	+	**allowance for the *flooding hazard* limit OR meander belt allowance** 20 times the bankfull channel width centred over the meander belt axis **OR** as determined by a study using accepted engineering principles	+	**erosion access allowance** 6 metres **OR** as determined by a study using accepted scientific, geotechnical and engineering principles

Figure 36: *Protection Works Standard:* Unconfined or Terrain-Dependent with Cohesionless Material


Hazardous lands limit
Protection works *
Meander belt allowance or Flooding Hazard limit
Erosion access allowance
* Protection works installed in environmentally sound manner and do not create or aggravate upstream/downstream hazards.
(not to scale)

Where the *protection works standard* is deemed too excessive or insufficient to address the severity of the natural hazards impacting on a particular site, mechanisms should be incorporated into the planning process providing the flexibility to undertake a study using accepted scientific, geotechnical and engineering principles to determine the *protection works standard*.

Where the municipality or planning board approves the study (studies) using accepted geotechnical, scientific and/or engineering principles, where applicable and appropriate, to determine the toe erosion, meander belt, stable slope and/or erosion access allowances, the *protection works standard* should then consist of the protection works plus the approved allowances and applied only in the area studied.

For additional information on what is considered "accepted geotechnical and/or scientific and engineering principles", the *MNR Technical Guide for River and Stream Systems* (1997) should be consulted.

iv) *Hazardous Sites*

Of the three types of *hazardous sites* (i.e., sensitive marine clays, organic soils, karst formations) protection works are generally considered to be inappropriate in areas of organic soils and karst formations (see Section 4.2.4 and the *MNR Technical Guide for Hazardous Sites* (1996) which outline additional considerations when dealing with these areas).

In areas involving sensitive marine clays (i.e., leda), where development may be considered within the least hazardous portions of the *hazardous sites*, the following *protection works standard* should be applied:

protection works (non-structural, structural works)	+	**allowance for stable slope** determined by a study using accepted geotechnical principles	+	**a hazard allowance** determined by a study using accepted scientific and engineering principles

As identified in Section 4.1.3, given the risks to life and property associated with sensitive marine clays, there are two key factors or issues that should be addressed when considering protection works and/or development within the *hazardous sites*. First, a minimum factor of safety of 1.5 is recommended. Secondly, the methods used to determine the hazard allowances behind the protection works should be dependent on whether there is or is not evidence of a retrogressive failure(s).

Regardless of the type of *hazardous sites* involved (e.g., unstable soils, unstable bedrock), due to the uniqueness and variability of local conditions associated with *hazardous sites*, the identification of a single "protection works standard" is impractical. As such, studies using accepted geotechnical, scientific and engineering principles should be undertaken to determine the appropriate protection works standards to be applied.

Where municipalities and planning boards have determined that *development* and *site alteration* may be considered within the least hazardous portions of the *hazardous sites*, mechanisms should be incorporated into the planning process to provide the flexibility to undertake a study using accepted geotechnical, scientific and engineering principles to determine the *protection works standard*. Where studies have been undertaken and approved, the *protection works standard* should then consist of the protection works plus the approved hazard allowances and applied only in the area studied.

c) *Access Standard*

Issues related to access (i.e., ingress, egress) should be addressed where development is being considered within the less hazardous portion(s) of either *hazardous lands* or *hazardous sites*. This includes access from either an individual development site or from the entire development area (e.g., shoreline or island communities, marina development, riverine subdivision) during flood, erosion and other emergencies.

In general, access is governed by the ability of motorized vehicles to enter and leave an area experiencing an emergency situation (e.g., flooding, erosion, wave action).

Although the current level of knowledge related to access is minimal, at best, the question of safety for the passage of vehicles basically involves one of two categories of concern:

- flood depth considerations affecting egress of private vehicles from flood susceptible areas; and
- flood depth affecting access of private and emergency vehicles to flood susceptible areas

In general, for private vehicles, water contact can critically affect the ignition and/or electrical system and the exhaust system making them inoperable. The necessity for these systems to be able to function properly in times of flooding are indisputably critical.

Emergency vehicles operate under similar constraints respecting electrical and exhaust systems. Most police vehicles and ambulances would be limited by exhaust considerations, although emergency vans are often better equipped to avoid splash problems since the key electrical components are designed higher above the road surface. Diesel fire vehicles with top exhausts appear best suited for flood conditions due to their higher road clearance.

Most assumptions regarding critical depth for the safe operation of vehicles are based upon water levels in the absence of waves (i.e., flooding situations within riverine environments). When determining access requirements for shoreline locations, consideration should also be given to the significant influence that wave action has on increasing flood depths. As such, access requirements in shoreline areas should be adjusted accordingly to account for the additional influences of other water related hazards (e.g., wave uprush, wave overtopping).

Generally, access requirements should be determined on a site by site basis and recognized during the design phase of development.

Issues of access (i.e., ingress/egress), whether to individual building sites or entire development areas, are best addressed on a more comprehensive and municipality-wide basis through the preparation of a Municipal Emergency Action Plan. Assistance in the establishment of options for site and/or area evacuation, the issuance of flood and storm warning and/or flood/storm alerts from local Conservation Authorities, and the provisions of emergency action programs (e.g., sandbagging, technical advise, etc.) should be developed in consultation with the local Conservation Authority, the Ministry of Natural Resources, the Office of the Solicitor General and other pertinent emergency management agencies. Where comprehensive Municipal Emergency Action Plans have been developed and adopted they should provide the required direction and assistance to municipalities in determining the requirements to be met in fulfilling access issues and concerns.

4.2.4 Additional Considerations When Dealing With *Hazardous Sites*

Areas of *hazardous sites* are unique in the sense that these natural hazards are generally not "addressed" through the use of *floodproofing* or *protection works* (i.e., other than leda clays which may involve the installation of protection works to address the first, but not the subsequent, retrogressive failures). They are also unique with respect to the general lack of scientific research and understanding that currently exists when trying to determine if proposed actions actually "address the hazards" such that risks to public health and safety are truly minimized. As such, this section discusses some of the concerns and cautions specific to *hazardous sites* that should be considered should development be contemplated.

a) Sensitive Marine Clays

Of concern in areas of sensitive marine clays (i.e., leda) is the potential severity and risks associated with developing in these areas. As discussed in earlier sections, the use of protection works are generally intended to address the FIRST retrogressive failure and, as such, may provide a false sense of security to area residents. Protection works, similar to the installation of motion detectors in the homes in areas of sensitive marine clays, are basically implemented in the interests of providing sufficient time or warning to evacuate the area in a timely manner during emergency situations.

Where *development* and *site alteration* is considered within areas of sensitive marine clays, the undertaking of studies using "*accepted scientific, geotechnical and engineering principles*" should be considered essential to ensuring that the proposed development is protected to the greatest degree possible.

b) Organic Soils

When defining the "area of provincial interest" for organic soils the relationship between the presence of organic and peat soils and wetlands was discussed in earlier section of this Training Manual (i.e., Section 4.1.3). Although Policy 2.3.1 identifies that *development* and *site alteration* should not permitted within *significant wetlands* south and east of the Canadian Shield, not all wetlands may be identified as being *significant wetlands*. Where *development* and *site alteration* may be considered under Policy 3.1.3, care must be taken to ensure that the intent of policies governing wetlands, which may not permit development, are not compromised.

Where development may be considered within these areas, Policy 3.1.3 identifies those matters that should be addressed for *development* and *site alteration* to potentially be considered within a *hazardous site* (e.g., hazards can safely be addressed, new hazards not created, existing hazards not aggravated, no adverse environmental impacts will result, and safe ingress/egress).

The construction of buildings, embankments, roadways or other types of structures and development across organic soils usually requires either the excavation and/or replacement of the organic material with engineered fill or the placement of fill on top of these soft compressible soil structure foundations. Economic and construction considerations often preclude total excavation and replacement. However, the alternative of construction on top of these highly variable soft organic and peat deposits is usually complicated by the difficulties associated with the short-term and long-term compression or settlement of the fill material as well as the potential presence of methane gas.

Due to the variable and complex nature and characteristics of these soil types, a study using "*accepted scientific, geotechnical and engineering principles*" should be used to determine the appropriateness and/or feasibility of placing development within or over top of organic and peat soils.

Given the variable nature of these soils, these studies should reflect or focus on local factors. Criteria normally considered in these studies may include, but are not limited to:

- locational analysis to identify the areas of organic and peat soils;
- composition analysis of the soil including structure, moisture content and compressibility;
- classifying or categorizing the soil based on composition for engineering and design purposes (e.g., Van Post System)
- determination of the appropriate materials to be used as fill or soil cover to prevent erosion and to enhance soil stability;
- determination of the appropriate angles for slopes cut into the soil to minimize erosion and to enhance soil stability (e.g., 5:1 horizontal to vertical for peat normally applied);
- determination of the procedures and materials required to safely vent any methane gas that is naturally produced; and
- in areas involving frozen organic soils (e.g., Northern Ontario), determination of the procedures and materials needed to thermo insulate permafrost soils where warranted.

A listing of suggested reference materials to assist in determining what is involved in such a study as well as additional technical information and direction related to organic soils is outlined in the *MNR Technical Guide for Hazardous Sites* (1996).

In Ontario, an additional source of information and guidance is the Ontario Building Code which has established guidelines and procedures which should be fulfilled when building in areas of organic soils to ensure structural integrity and soundness.

c) Karst Formations

Due to the inherent complexity and variability of conditions within areas of karst formations and the highly localized and often undetected existence of these formations, a study using "*accepted scientific, geotechnical and engineering principles*" should be used to determine the appropriateness and/or feasibility of placing development within or over top of karst formations.

Given the complexity and variability of conditions related to karst formations, these studies should reflect or focus on local factors. Criteria normally considered may include, but are not limited to:

- locational analysis to identify the karst environment;
- an analysis of the stage and condition of the development of the karst landform;
- determination of the bearing capacity of the karst formation including:
  - identifying a suitable location for the siting of building and structures
  - determining the appropriate bearing values and construction procedures
- investigating and delineating the extent of karst formation using:
  - aerial photography for site reconnaissance
  - geophysical investigations (e.g., ground penetrating radar, electromagnetic conductivity measurements, micro - gravity, resistivity, spontaneous potential methods, etc.)
  - drilling for detailed design of the development
- investigating and determining the appropriate remedial measures to be used, where warranted through the use of:
  - reduction of conventional bearing pressures (e.g., driving or drilling piles or the use of batter piles)
  - coverings to bridge or cap the cavities
  - compaction and consolidation filling and/or grouting measures

Sources of information providing guidance in developing in areas of karst formations may include those developed by other agencies. For example, the states of Florida and Kentucky have formulated full scale building and structural foundation codes to control and ensure the proper and safe development of subsurface structures in karst formations.

In Ontario, there may be localized studies that have resulted in locally instituted guidelines and standards being developed. Where these studies have been undertaken using *accepted scientific, geotechnical and engineering principles* they may be considered for application in the area studied.

Finally, a listing of suggested reference materials as well as addition technical information and direction is provided in the *MNR Technical Guide for Hazardous Sites* (1996).

4.2.5 Suggested Approach for Balancing Development Interests and Natural Hazards (Physical and Biological Processes)

Addressing an individual or combination of natural hazards (e.g., erosion and flooding within a watercourse or along a shoreline) should involve a comprehensive examination of the physical and biological processes influencing the site under study to determine the most appropriate management response.

Consistent with the goals, objectives and principles of the provincial natural hazards management program, hazard management responses or practices are traditionally grouped into three primary categories:

- **prevention**
- **non-structural protection**
- **structural protection**

It has long been the position in the Province of Ontario that **prevention responses are the preferred approach** in addressing natural hazards. Rather than modifying the natural hazards through the installation of protection works, prevention approaches promote the application of effective land use planning and the regulation of development to prevent and/or minimize damages associated with natural hazards. This is normally achieved though:

- hazard allowances;
- minimum building elevation/opening requirements; and
- property acquisition.

Essentially, the intent of prevention responses is to direct or locate development outside of or beyond the *hazardous lands* and *hazardous sites.* In situations where development may be considered and where all of the concerns associated with addressing the natural hazards may be achievable (i.e., as outlined in Policy 3.1.3), development should be directed to or located within the least hazardous portions of these areas.

Non-structural protection works are essentially activities that do not involve the construction or the placement of significant additional structures or materials within the area of provincial interest including:

- relocation of buildings/structures;
- floodproofing;
- bluff measures (shorelines);
- dune enhancement (shorelines); and
- soil bioengineering, live plant materials (e.g., fascines, wattles, brush layering) (rivers, shorelines).

Structural protection works involve the construction and/or placement of significant additional structures and/or materials within the area of provincial interest including:

- filling (hazardous sites, shorelines, rivers);
- weirs (rivers);
- soil drainage works (shorelines, rivers);
- biotechnical stabilization (e.g., vegetated cellular grids, live crib walls and rock walls)(rivers, shorelines);
- retaining walls (e.g., blocks, concrete, timber, sheet piling (rivers);
- reinforced earth, geogrids (rivers, shorelines);
- removal/filling of hazard (hazardous sites (Karst));
- dyking (shorelines, rivers);
- dams (rivers);
- beach nourishment (shorelines);
- revetments (shorelines, rivers, hazardous sites);
- seawalls (shorelines);
- groynes (shorelines);
- artificial headlands (shorelines); and
- detached breakwaters (shorelines).

Structural protection works may also involve the use of **biotechnical stabilization** techniques and/or procedures. Whenever possible, biotechnical stabilization techniques and/or procedures should be used in the place of structures listed above.

Where the selected natural hazard management response involves any form of protection work (i.e., structural or non-structural), careful consideration and evaluation should be given to the immediate and broader geomorphological, ecological and socio-economic impacts of the selection. This is particularly important given that no one element of the ecosystem evolves or operates independent of all other elements. All physical and biological elements or processes are inherently interdependent and should be given due consideration in any decision-making process.

Where there is a potential for development to safely occur within an area of provincial interest, the development should address all of the *established standards and procedures* related to floodproofing, protection works and access. In applying these *established standards and procedures*, it should be recognized that there are no guarantees that any protection work will offer protection for 100 years. In addition, where **"addressing the hazards"** involves the installation of protection works, the protection works should be coupled with the appropriate allowance(s) (e.g., for stable slope, toe erosion, and/or hazard allowances), where appropriate (e.g., see Section 4.2.3 of this Training Manual) to:

- recognize and address the inherent uncertainties associated with determining the hazard(s);
- accommodate the spatial and temporal variability of the natural hazard(s) within the area of provincial interest and surrounding environments (e.g., upstream/downstream, updrift/downdrift);
- provide a margin of safety related to the potential failure of the protection work; and/or
- allow for safe access to and from the site during emergencies.

Although prevention approaches are the preferred natural hazard management response, protection works should not be considered as inherently negative. Clearly, in some locations, protection works may prove necessary and may provide the only viable solution to an existing natural hazards management concern. This may be particularly true where a very large existing investment in buildings or infrastructure must be maintained or protected, where waterfront parks offer valuable and often the only recreational space in highly urbanized communities, or where sites of very significant historical, social or cultural importance to the public are involved.

Conversely, there are numerous locations where protection works should not be considered including, but not limited to:

- areas of active erosion which provide essential sediment source material for downdrift beach shoreline environments and downstream riverine environments;

- areas where the installation of protection works would result in unacceptable environmental impacts, even if the selected protection works were considered appropriate to address the existing physical hazards; and

- areas where the protection works would create a new hazard or aggravate an existing hazard at either upstream/downstream riverine locations or updrift/downdrift shoreline locations (e.g. groynes trap or deflect alongshore transport resulting in a reduced quantity of sediment on beaches at adjacent shoreline properties thereby increasing flood and erosion hazards).

The selection of an appropriate natural hazard management response or action to address a natural hazard(s) should be determined by the physical characteristics of the site, the type of natural hazard(s) involved, the purpose of the selected action, the environmental impacts associated with the selected action and/or practices, and the nature of the proposed development and/or land use.

To provide guidance on how to address the hazards, both physical and biological, when evaluating whether or not an area, particular location or type of development, including any works, should be considered, the following Suggested 7 Step Procedure has been developed.

a) Suggested 7 Step Procedure: Addressing the Hazards

This procedure is designed to aid decision-makers in evaluating an area, or particular location, within *hazardous lands* and *hazardous sites* and in ensuring that consideration is given to both the physical and biological influences and impacts when selecting which, if any, natural hazard management response (e.g., prevention, non-structural protection works or structural protection works) would provide the "best management practice" given local site conditions. The steps include:

- **Step 1: Identify Hazards;**
- **Step 2: Identify Development Proposed Within the *Hazardous Lands* or *Hazardous Sites*;**
- **Step 3: Identify Appropriate Hazard Management Response;**
- **Step 4: Determine Potential Impacts to Physical Processes and Characteristics;**
- **Step 5: Assess Off-Site Physical Impacts;**
- **Step 6: Assess Biological or Environmental Impacts; and**
- **Step 7: Mitigate Minor Impacts of Preferred Hazard Management Response.**

A flowchart of the Suggested 7 Step Procedure for addressing the hazards is presented in Figure 37.

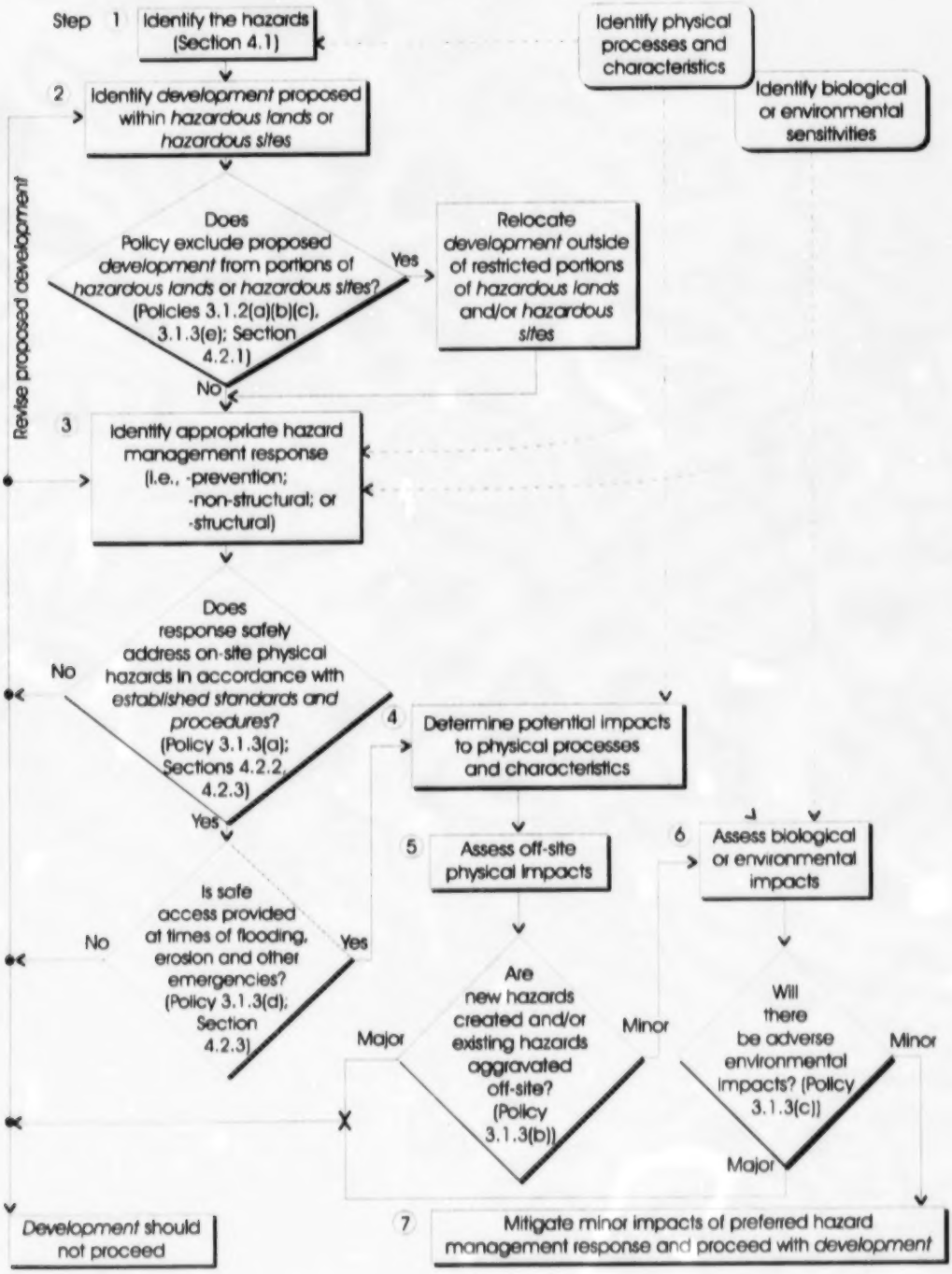
The Suggested 7 Step Procedure focuses on some basic questions and issues that should be addressed in any development decision-making process. It is recognized that some natural hazards may be more complex than others (e.g., shoreline locations subject to flooding, erosion and dynamic beaches when compared with small, isolated karst geology formations). As such the level of evaluation should be site specific and directly proportional to such factors as the size, severity, and type of risks and the potential physical and biological impacts that may result.

To further clarify how the Suggested 7 Step Procedure may be applied, discussions specific to its application on the *Great Lakes - St. Lawrence River System* are provided in Appendix 1.0. For additional technical information and direction the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996) should be consulted.

i) Step 1: Identify Hazards

As discussed in Section 4.1, the Policy defines the areas of provincial interests as being *hazardous lands*, which includes lands adjacent to the shorelines of the *Great Lakes - St. Lawrence River System* and *large inland lakes* which are impacted by *flooding*, *erosion* and *dynamic beach hazards* and lands adjacent to *river and stream systems* which are impacted by *flooding* and/or *erosion hazards*, and *hazardous sites*. The first step in this process involves identifying, or delineating, the areas of provincial interest. Completion of this step normally requires a sufficient level of understanding of the physical processes and characteristics.

Figure 37: Suggested 7 Step Procedure: Addressing the Hazards


Step 1 Identify the hazards (Section 4.1)
Identify physical processes and characteristics
Identify biological or environmental sensitivities
2 Identify development proposed within hazardous lands or hazardous sites
Revise proposed development
Does Policy exclude proposed development from portions of hazardous lands or hazardous sites? (Policies 3.1.2(a)(b)(c), 3.1.3(e); Section 4.2.1)
Yes
Relocate development outside of restricted portions of hazardous lands and/or hazardous sites
No
3 Identify appropriate hazard management response (i.e., -prevention; -non-structural; or -structural)
Does response safely address on-site physical hazards in accordance with established standards and procedures? (Policy 3.1.3(a); Sections 4.2.2, 4.2.3)
No
Yes
4 Determine potential impacts to physical processes and characteristics
5 Assess off-site physical impacts
6 Assess biological or environmental impacts
Is safe access provided at times of flooding, erosion and other emergencies? (Policy 3.1.3(d); Section 4.2.3)
No
Yes
Are new hazards created and/or existing hazards aggravated off-site? (Policy 3.1.3(b))
Major
Minor
Will there be adverse environmental impacts? (Policy 3.1.3(c))
Major
Minor
Development should not proceed
7 Mitigate minor impacts of preferred hazard management response and proceed with development

ii) Step 2: Identify Development Proposed Within the *Hazardous Lands* or *Hazardous Sites*

Except for certain restrictions (i.e., Policy 3.1.3, as discussed in Section 4.2.1), there exists the flexibility to consider *development* and *site alterations* to be located within the least hazardous portion of the *hazardous lands* and/or *hazardous sites*. The second step then involves identifying the size and nature of the development that is proposed within the *hazardous lands* and/or *hazardous sites*. This is essential since the characteristics of the proposed development activity, or the resulting land use, can influence the type of hazard management response to be applied. For example, a high-density residential development will obviously require a greater degree of protection from hazards than non-habitable buildings.

Development can generally be grouped into three major categories (see Section 4.2.3):

- multi-lot, large lot and large scale development;
- residential or habitable infilling, redevelopment, replacement, major additions/alterations, minor additions/alterations; and
- non-habitable buildings and structures.

When undertaking this step, it should be acknowledged that Policy 3.1.2 identifies that *development* and *site alterations* should not be permitted within *defined portions of the dynamic beach*, *defined portions of the one hundred year flood level along connecting channels*, or in a *floodway*. Also, Policy 3.1.3(e) identifies that *institutional uses* or *essential emergency services* or the disposal, manufacture, treatment or storage of *hazardous substances* should not be permitted within *hazardous lands* and/or *hazardous sites*. All portions of the proposed *development* should then be relocated outside the restricted areas of the *hazardous lands* and/or *hazardous sites*.

iii) Step 3: Identify Appropriate Hazard Management Response

As discussed in Sections 4.2.2 and 4.2.3, where *development* and *site alteration* may be considered within any of the areas of provincial interest, the *development* and *site alteration* should fulfil the *established standards and procedures* respecting:

- floodproofing;
- protection works; and
- access.

Step 3 involves an assessment of whether or not the selected hazard management response (i.e., prevention, non-structural or structural protection works) is considered to be appropriate, fulfils each of these standards and safely address the on-site physical hazards. Completion of this step normally requires a sufficient level of understanding of the physical processes and characteristics of the site.

If it is determined that these standards cannot be fulfilled, or if the proposed hazard management response does not safely "address the on-site physical hazards" (e.g., erosion, flooding, etc.; Policy 3.1.3(a)) or if safe ingress and egress is not provided at times of flooding, erosion and other emergencies (i.e., Policy 3.1.3(d)), then an alternative hazard management response should be selected and/or the proposed development revised.

iv) Step 4: Determine Potential Impacts to Physical Processes and Characteristics

One of the primary issues when considering protection works to address natural hazards is the need to assess the impacts of the selected protection works on the area's physical processes and characteristics.

Although a particular hazard management response may appropriately address the local or on-site flood and/or erosion hazard(s), the physical characteristics of the protection works (e.g., structural form and slope, size of material, permeability, etc.), the methods used in construction, the methods of maintenance, and the post-design life measures may individually and/or collectively affect the characteristics and physical processes of a given location. The "affects" or impacts may in turn cause harm to the ecosystem and pose physical risk or harm by increasing or exacerbating hazards on surrounding properties.

Step 4 essentially involves identifying the potential influences and impacts of the proposed hazard management response to the physical processes and characteristics. Completion of this step normally requires a sufficient level of understanding of the physical processes and characteristics.

In addition to understanding and addressing the type and magnitude of impacts on the physical processes and characteristics on-site, consideration should also be given to the spatial extent of the physical impacts in order to assess the impacts off-site (e.g., how far upstream/downstreamthe physical impact is determined to extend; see Step 5). Evaluation of the spatial extent of the physical impacts is dependent on such factors as the type, design, configuration and sometimes the timing of the installation of protection works. The resultant impact(s) on the physical processes is also dependent on the physical characteristics of the area in which the works are being installed. For example, is the native soil structure highly susceptible to disturbance, is the area exposed, is it partially sheltered, and what is the magnitude and duration of the forces (e.g., wind, waves, flood flows).

Effective ecosystem and natural hazards management generally involves managing not only the physical hazards (e.g., flooding, erosion, dynamic beaches, unstable soils, unstable bedrock), but also understanding and accommodating the potential impacts of any such actions on the local environment or ecosystem. Step 6 deals with the biological impacts.

v) Step 5: Assess Off-Site Physical Impacts

Beyond the consideration of the range, magnitude and consequences of protection works on **on-site** physical processes and characteristics, one should also give consideration to the potential range, magnitude and consequences of the same protection works on **off-site** locations or surrounding properties (e.g., updrift/ downdrift shoreline properties, upstream/downstream riverine properties).

Evaluations of potential **physical impacts** are often described in terms of **major** or **minor impacts**. For clarification and consistency, the following definitions specific to natural hazards should apply:

- **Minor physical impacts** are defined as being of short-duration, where the impact can be mitigated through alterations in design or the selection of an alternative form of protection work, where the impact can be addressed by a change in the timing of construction, where there is likely to be a high rate of recovery, and where there is a low potential for spin-off effects.

- **Major physical impacts** are defined as having long-term and permanent adverse impact on the on-site/off-site physical characteristics and/or processes, where the impact(s) cannot be mitigated through changes in design and/or timing, and where there is a high potential for direct and/or indirect spin-off effects.

Where major off-site physical impacts result, the development should not considered to be fulfilling the intent of the policy (e.g., Policy 3.1.3(b), development is not to aggravate existing hazards, create new hazards).

Where new hazards are created and/or existing hazards aggravated, one of three options should be implemented:

- an alternative method of "addressing the hazard" should be considered; or
- the development should be revised; or
- the development should not be permitted.

Where minor physical impacts are identified, a determination of whether this impact(s) can be further reduced using another form of protection works or an alteration to the design, installation method or timing should be considered.

vi) Step 6: Assess Biological or Environmental Impacts

The environmentally sound management of a particular location essentially involves an understanding not only of the physical processes impacted by various protection works, but also of the effects that these physical processes, and any changes to them, have on the ecosystem. The more complex or diverse the physical characteristics and processes that are shaping and reshaping the development site, the more diverse the range of habitat types for plant and animal species. A thorough examination and understanding of these diversities, therefore, would help to ensure that potential adverse environmental impacts are addressed and minimized.

The gradual encroachment of development on sensitive ecosystems have in the past resulted in impacts which were frequently overlooked until it was too costly, practical or late to remedy or recover affected habitats. It is essential, therefore, in any decision-making process, to ensure that environmental concerns are considered as an integral part of managing a particular location, and not as an isolated study component to be addressed at a later or last stage of the process. For environmental concerns to be duly recognized and properly evaluated and addressed, they should be considered at all stages of the land use planning process, from the formulation of alternative development strategies to the plan implementation and post-development monitoring stage.

To complete Step 6 essentially involves the evaluation of the biological or environmental sensitivities associated with a particular development site or area and an understanding and recognition of their importance to the ecosystem as a whole. As well, consideration should also be given to the potential physical impacts and their spatial extent developed during Step 4. Step 6 then builds on this knowledge by undertaking an assessment of how the biological elements and processes are impacted by the introduction of the development and any associated non-structural or structural works that may be proposed.

- **Ecosystem**

Habitat, in general, is the combination of living and non-living things which provide a particular species with the resources it needs to complete its life cycle. These may include soil, water, air, rocks, rain, heat and the other plants and animals which provide the food needed for survival. Maintaining a diversity of habitats is essential to accommodating the needs of many species and to ensuring the continued diversity of wild life. The term "wild life", as defined in the Wild Life Strategy for Ontario (1991), includes all wild animals, birds, reptiles, amphibians, fish, invertebrates, as well as, plants, algae, bacteria, and other wild organisms. All species have different habitats, which collectively influence each other and function together as an ecological system or ecosystem.

When assessing the biological or environmental sensitivities within natural hazard areas, there should also be the recognition that the use, existence and management of wild life species may not restricted to these "areas of provincial interest". As such, any decisions made relative to natural hazards should also consult the broader resource planning and management interests of the implementing agencies normally identified in ecosystem-based resource management plans (e.g., shoreline, watershed, subwatershed management plans).

The biological component of the ecosystem encompasses all wild life and the habitat that supports it. Every wild life species has its own habitat requirements, which can change depending on the stage of its life cycle, the season or even the hour of the day. Areas involving water are particularly important in terms of wild life habitat. For example, areas surrounding wetlands, ponds, rivers and lakes are used by more wild life species than any other habitat type.

An analysis of the significance of the various biological elements of the ecosystem and their susceptibility to disturbance from the placement or design of various protection works is often very difficult due to the interconnections and linkages between these elements.

- **Function, Significance and Susceptibility to Disturbance**

When evaluating the potential impacts of any proposed activities, one normally undertakes an assessment of the function and significance of the habitat, and secondly, an assessment on the susceptibility of the habitat to disturbance.

The function and significance of a habitat includes the interrelationships between it and other components of the ecosystem, the general importance of the habitat type in terms of its economic or social value, and its intrinsic values in providing habitat for endangered species. Discussions on the susceptibility of a habitat normally relate to the response of a particular habitat to stress or to changes being placed on it. In general, habitats that can withstand this stress, or which can adapt or recover quickly are considered to have a low susceptibility to disturbance. Conversely, where stress or change to the ecosystem can result in permanent or irreversible changes to the diversity and number of shore habitats and associated wild life species, such habitats are considered to have a high susceptibility to disturbance.

When discussing potential options for addressing natural hazards, earlier components of this Training Manual identified three general categories of management approaches:

- **prevention**
- **non-structural**
- **structural**

Prevention techniques such as the siting of buildings landward of the natural hazard limits and property acquisition and with some non-structural protection works such as building relocation and floodproofing measures normally do not require major alterations or disturbance to the local environments within areas of natural hazards. Where these measures are undertaken with minimal disturbance, the environmental impacts and potential for long-term disturbance to sensitive habitats with these measures are normally considered to be negligible.

Conversely, there are some non-structural approaches to addressing natural hazards (e.g., filling, bluff measures, beach nourishment in shoreline areas), that require some alteration of the local environment. Although the magnitude of impact is often directly proportional to the level of intrusion and disturbance, these measures may add new stressors to susceptible habitats but often provide an opportunity to enhance environmental conditions if undertaken properly (e.g., stabilization of shoreline dune vegetation).

Of the three general categories of protection works, structural protection works have the potential to cause the greatest magnitude and range of spatial and temporal environmental impacts depending on the susceptibility of the biological communities and their associated habitats to disturbance.

- **Impact Criteria**

The relative significance of the biological impacts associated with various protection works are usually evaluated based on the following criteria:

- **importance**
- **spatial extent**
- **duration of effect**
- **recovery**
- **mitigation**
- **cumulative effects**

- **Importance**

This addresses the significance or the value attached to the potentially affected area as a result of such factors as its location, uniqueness or importance for wild life.

For example, there are many areas along the *Great Lakes - St. Lawrence River System* that have been identified as having high value or significance due to the special functions or habitats which they provided to a diverse range of wild life. These include endangered species habitat, spawning areas, Areas of Natural and Scientific Interest, provincially and locally significant watersheds, Environmentally Significant Areas, and areas deemed to be of Natural Heritage. As such, these areas should be given special consideration and attention in planning for a protection works structure.

- **Spatial Extent**

The environmental impacts associated with various protection works can occur within the immediate site or vicinity of the works and/or surrounding the site area (e.g., upstream/downstream for riverine sites).

Impacts in the immediate vicinity of the protection works can result from both large-scale (e.g., construction of a large breakwater at a harbour entrance) and small-scale activities (e.g., clearing of vegetation for a revetment).

For example, typical **on-site environmental impacts** of shore protection works or related shore development activities may include:

- placement of fill material which covers aquatic plants and bottom substrates;
- changes to nearshore substrates on which fish species may spawn (e.g., cobbles);
- alteration of water levels in periodically flooded areas which may restrict spawning areas and waterfowl habitat;
- removal or clearing of shoreline vegetation which provides shade, bank stabilization and habitat for wild life; and
- removal of material from the nearshore such as boulders, cobbles, and stumps affect fish feeding grounds by reducing the potential habitat for food organisms (e.g., prey species).

Typical **off-site environmental impacts** for shoreline areas may include:

- release of sediments into the water column;
- changes in sediment supply and alongshore sediment transport; and
- change to substrates covering aquatic plants, bottom substrates, and plants.

Rarely are there environmental impacts which are limited to the immediate site of the activity or disturbance. For this reason, careful consideration and evaluation of on-site and off-site impacts should be addressed in any development decision-making process.

- **Duration of Effect**

Evaluation of this criteria addresses the length of time associated with the activity and its possible environmental impacts. Such impacts are normally identified in terms of their short-term or long-term duration.

There are three key temporal phases associated with protection works:

- construction-related activities;
- operation and function of the protection works during its design life; and
- post-design life.

Short-term environmental impacts are generally associated with construction activities and may often be avoided through alterations and/or modifications in project design or through changes in construction practices (e.g., fencing of the access route to the site to minimize surrounding disturbance, use of silt screens/fencing).

Long-term environmental impacts are generally the result of the project design and occur following construction. For example, the direct loss of a fish spawning bed by the placement of a shoreline groyne would be considered a long-term impact.

During the post-design life phase, when the structure has failed or is no longer functioning as designed, environmental impacts may be more difficult to predict. Generally, however, these impacts will likely occur on-site and on areas surrounding the development site.

- **Recovery**

The susceptibility of habitat and its ability to recover following a stress placed on it must be considered. For example, the re-establishment of a small area of shoreline vegetation when a construction road is no longer required, may be quick to recover and may require little input. Conversely, other environmental impacts, such as those associated with the alteration of a drainage pattern to a wetland may be irreversible.

- **Mitigation**

The use of standard mitigation measures or practices are normally required to alleviate or reduce the environmental impacts associated with a particular development activity. Mitigation measures can be employed during the construction phase or in the actual designing stage of a particular structure or activity to reduce associated environmental impacts.

When standard mitigation measures will not substantially reduce environmental impacts (e.g., loss of habitat will occur), compensation for the displaced habitat may be considered and/or required. As an example, compensation plans associated with the potential destruction of fish habitat must be approved by the Federal Department of Fisheries and Oceans.

- **Cumulative Impacts**

Although the environmental impacts associated with a single development activity may be considered to be small or minimal, the addition of this impact to all others being placed on an already stressed ecosystem may have the cumulative impact of causing serious and potentially irreversible degradation. Careful consideration of the cumulative impact of any and all development activities should be assessed and determined through ongoing consultation with all agencies having an interest in the ecosystem.

Evaluation of these criteria is usually based on the resultant **major** or **minor biological impacts**:

- **minor biological or environmental impacts** are those which can be mitigated, that is, the proposed structure or activity will cause impacts which can be mitigated through changes in the design and/or timing of the activity. Confining impacts to what is considered a minor level, as opposed to a major level impact, is contingent on having an impact of short duration, the availability of mitigation practices, a high rate of recovery, and a low potential for spin-off effects.

- **major biological or environmental impacts** occur when the structure or activity has significant long-term or permanent adverse environmental impacts on the net productivity of the habitat on-site or off-site. A major impact can occur when the impact is of long-term duration, the rate of recovery of the habitat is low, there is a high potential for spin-off or indirect effects and/or the area affected is considered to be critical habitat.

The relative importance of each of these criteria and the rigour with which they are evaluated may vary with each project. As such, there should be consideration given to the type and size of the project and the sensitivity of the location when deciding on the level of study that is to determine whether or not the development is being undertaken in an environmentally sound manner. Where the development cannot be undertaken in an environmentally sound manner (e.g., adverse environmental impacts result) alternative works should be considered or the development should not be permitted.

vii) Step 7: Mitigate Minor Impacts of Preferred Hazard Management Response

The proposed *development* and *site alteration* may proceed where all of the matters outlined in Policies 3.1.2 and 3.1.3, as outlined in Steps 1 through 6, and any minor impacts are mitigated by alterations to the design and/or to the timing and method of installation.

5.0 INFORMATION SOURCES AND GLOSSARY OF TERMS

There are numerous sources of technical information to support the implementation of the provincial policies related to natural hazards. The following listing should not be considered as being all inclusive. More detailed and extensive listings of information sources are contained in the individual Technical Guides developed by the Ministry of Natural Resources.

The following listing represents the primary sources of information pertaining to each of the four policy areas governing natural hazards:

5.1 *Great Lakes - St. Lawrence River System*

- ***Great Lakes - St. Lawrence River Shoreline Technical Guide* (MNR, 1996)**

. *Wave Uprush and Wave Overtopping*, Atria Engineering Inc., 1997.
. *Geotechnical Principles for Stable Slopes*, Terraprobe Limited, 1997.
. *Cross-Profile Sediment Transport Models*, Acqua Engineering Inc., Atria Engineering Inc., 1995.
. *Beach and Dune Management Guide*, OMNR and Geomatics International Inc., 1995.
. *Great Lakes Shoreline Classification and Mapping Study: Canadian Side*, Geomatics International Inc. and Dr. Robin Davidson-Arnott, 1995.
. *Wave Hindcasting Databases and Studies:*
  . Lakes Ontario and Superior, MacLaren Plansearch, 3 Volumes, 1988.
  . Lake Huron and Georgian Bay, Philpott Associates, 4 Volumes, 1988.
  . Lakes Erie and St. Clair, Sandwell Swan Wooster, 3 Volumes, 1988.
. *Littoral Cell Definition and Sediment Budgets for Ontario's Great Lakes*, Reinders, 1988.
. *Canada/Ontario Flood Damage Reduction Program* (Shoreline Hazards Mapping),1987-95.
. *Canada/Ontario Great Lakes Erosion Monitoring Program: 1973-1980*, G.L. Boyd, 1981.
. *Canada/Ontario Flood and Erosion Prone Area Maps*, 1978.
. *Canada/Ontario Great Lakes Shore Damage Survey*, 1978.
. *A Summary of Policies and Guidelines for the Protection of Aquatic Habitat in Ontario*, DFO and MNR, 1994.

5.2 *Large Inland Lakes*

- ***Large Inland Lakes Technical Guide* (MNR 1996)**

. *Wave Uprush and Wave Overtopping*, Atria Engineering Inc., 1997.
. *Geotechnical Principles for Stable Slopes*, Terraprobe Ltd., 1997.
. *Cross-Profile Sediment Transport Models*, Acqua Engineering Inc., Atria Engineering Inc., 1995.
. *Beach and Dune Management Manual*, OMNR and Geomatics International Inc., 1995.

5.3 *River and Stream Systems*

- ***River and Stream Systems Technical Guide* (MNR 1997)**

. *Geotechnical Principles for Stable Slopes*, Terraprobe Ltd., 1997.
. *Stream Analysis and Fish Habitat: A Field Manual*, R.W. Newbury and M.N. Gaboury, 1994; 2nd printing.

- *Report on Natural Channel Systems An Approach to Management and Design*, Ontario Ministry of Natural Resources, 1996.
- *Watercourse and Valleyland Protection Policies*. Watershed Planning Division, Credit Valley Conservation Authority, 1992.
- *Geotechnical Study Slope Classification and Setback Criteria Credit Valley Watershed*, Ontario. Report prepared for the Credit Valley Conservation Authority, Golder Associates Ltd., 1990.
- *Learning From the River. 'Natural' Channel Design: Perspectives and Practice.* Based on the First International Conference on Guidelines for 'Natural' Channel Systems, Leopold L.B. and D.L. Rosgen, 1994.
- *Valley and Stream Corridor Management Program*, Metropolitan Toronto and Region Conservation Authority, 1994.
- *Rivers: Form and Process*, Longman Group Ltd., Essex, England, Morisawa, M., 1985.
- *Canada/Ontario Flood Damage Reduction Program* (Flood Plain Hazards Mapping), 1978-95..

5.4 *Hazardous Sites*

- ***Hazardous Sites Technical Guide (MNR, 1996)***

- **Sensitive Marine Clays (Leda)**
- *Geotechnical Slope Stability Study: Sensitive Marine Clays in Southwestern Ontario - Erosion Policy,* Report to Ontario Ministry of Natural Resources, Golders, 1988.
- *Terrain Analysis of the South Nation River From Casselman to Lemieux,* Report for the South Nation River Conservation Authority, Gorell, G., 1984.
- *Great Lakes - St. Lawrence River Shorelines Technical Guide,* Appendices A4.2 and A4.3, OMNR, 1996.
- *Slope Stability Study of the South Nation River and Portion of the Ottawa River,* OGS Miscellaneous Paper 112, Poschmann, A.S., Klassen, K.E., Klugman, M.A. and Goodings, D., 1983.
- *Landslides in Canadian Sensitive Clays: A State of the Art,* Proceedings 4th Symposium on Landslides, Toronto, Vol I, pp.141-153, Tavenas, F., 1984.

- **Organic (Unstable) Soils**
- *Geotechnical Classification of Peats and Organic Soils: Testing of Peats and Organic Soils,* ASTM STP 820, P.M. Jarrett (Ed.), American Society for Testing and Materials, pp. 157-191, Landva, A.O., Korpijaakko, E.O. and Pheeney, P.E., 1983.

- **Unstable Bedrock (Karst)**
- *Earth,* W.H. Freeman and Co., USA, Press, F., and Siever, R., 1982.

5.5 Glossary of Terms

This following list of definitions does not include those which were identified in the *Provincial Policy Statement* (May 1996). As the *Provincial Policy Statement* (May 1996) should be read in conjunction with this *Training Manual* the definitions listed below are intended to augment those identified in the *Provincial Policy Statement* and supporting *Interpretive Handbook* and to aid in the interpretation and understanding of this *Training Manual*.

Accepted Engineering Principles refers to those current coastal and hydraulic engineering principles, methods and procedures that would be judged by a peer group of qualified engineers (by virtue of their training and experience), as being reasonable for the scale and type of project being considered, the sensitivity of the location, and the potential threats to life and property.

Accepted Geotechnical Principles refers to those current geotechnical engineering principles, methods and procedures that would be judged by a peer group of qualified engineers (by virtue of their training and experience), as being reasonable for the scale and type of project being considered, the sensitivity of the location, and the potential threats to life and property.

Accepted Scientific Principles refers to those current principles, methods and procedures, which are used and applied in disciplines such as geology, geomorphology, hydrology, botany and zoology, and would be judged by a peer group of qualified specialists and practioners (by virtue of their training and experience), as being reasonable for the scale and type of project being considered, the sensitivity of the location, and the potential threats to life and property.

Address refers to those standards and procedures intended to alleviate or reduce the impacts associated with flooding, erosion and other water related hazards which are used and applied in current coastal and hydraulic engineering, geotechnical and scientific practices.

Adverse Environmental Impacts refers to those physical, biological and environmental changes which are of long-term duration, where the rate of recovery is low, where there is a high potential for direct and/or indirect effects and/or where the area is considered to be critical habitat or of critical significance to the protection, management and enhancement of the shoreline ecosystem.

Average Annual Recession Rate refers to the average annual linear landward retreat of a shoreline or river bank.

Bank (*Great Lakes - St. Lawrence River System* and *large inland lakes*) refers to those sections of the shoreline formed in bedrock, non-cohesive or cohesive sediments where the land rises steeply away from the water such that the elevation of the top of the slope above the base (toe) of the slope is less than 2 metres and the average slope angle exceeds 1:3 (= 18 degrees).

Bankfull Discharge is the formative flow of water that characterizes the morphology (shape) of a fluvial channel. In a single channel stream, "bankfull" is the discharge which just fills the channel without flowing onto the flood plain.

Bluff (*Great Lakes - St. Lawrence River System* and *large inland lakes*) refers to those sections of the shoreline formed in non-cohesive or cohesive sediments where the land rises steeply away from the water such that the elevation of the top of the slope above the base or toe of the slope is greater than 2 metres and the average slope angle exceeds 1:3 (= 18 degrees).

Channel Configuration refers to the type or morphology of a river or stream channel as determined by a the interaction of a number of channel related factors including width, depth, shape, slope and pattern.

Cliff (*Great Lakes - St. Lawrence River System* and *large inland lakes)* refers to those sections of the shoreline normally formed in bedrock where the land rises steeply away from the water such that the top of the slope above the base or toe of the slope is greater than 2 metres and the average slope angle exceeds 1:3 (= 18 degrees).

Critical Flood Depth and Velocity refers to a maximum depth and velocity of flooding water in a flood plain such that further increases in depth and/or velocity may result in threats to life and property damage.

Drainage Basin is the area of land, surrounded by divides, that provides runoff to a fluvial network that converges to a single channel or lake at the outlet.

Dynamic Balance or Nature refers to a system that is continuously altering itself to adjust to constant changes of its component parts.

Environmentally Sound refers to those principles, methods and procedures involved in addressing the protection, management and enhancement of the ecosystem which are used in disciplines such as geology, geomorphology, hydrology, botany and zoology and applied in the study of shoreline and fluvial processes, vegetation, wildlife and aquatic habitat resource management.

Factor of Safety refers to the ratio of the resistance or strength of a material or structure to the applied load. In geotechnical engineering, it refers to the ratio of the available shear strength to shear stress on the critical failure surface.

High Magnitude refers to an event that is of great importance in terms of its impacts.

Humification is the soil forming process that transforms plant tissues into organic matter, on or in soil.

Hydraulic Flow refers to the flow of water in a channel as determined by such variables as velocity, discharge, channel roughness and shear stress.

Lakeward refers to a perspective from the land towards the lake or river.

Landward refers to a perspective from the lake or river toward the land.

Largest Amplitude Meander refers to the meander with the largest measured amplitude in a meandering reach. Amplitude is measured mid-channel to mid-channel and is the horizontal distance perpendicular to the longitudinal axis between two bends in the fluvial system.

Littoral Cell refers to a self-contained shoreline sediment system that has no movement of sediment across its boundaries. The alongshore limits are defined by natural formations or artificial barriers where the net sediment movement changes direction or becomes zero.

Low Plain (*Great Lakes - St. Lawrence River System* and *large inland lakes*) refers to those sections of the shoreline formed in non-cohesive or cohesive sediments where the land rises gently away from the water.

Meandering System refers to a dynamic system where semicircular curves or bends develop in a fluvial system resulting from erosion of sediment on the outer-bank and deposition of sediment on the inner-bank of the curves or bends. Erosion and deposition processes are themselves dynamic in response to channel configuration, hydraulic flow and sediment yield.

100 Year Monthly Mean Lake Level (*Great Lakes - St. Lawrence River System* and *large inland lakes)* is defined as the monthly mean lake level having a total probability of being equalled or exceeded during any year of 1%. Monthly mean level refers to the average water level occurring during a month computed from a series of readings in each month.

100 Year Wind Setup (*Great Lakes - St. Lawrence River System* and *large inland lakes)* is defined as the wind setup having a total probability of being equalled or exceeded during any year of 1%. Wind setup refers to the vertical rise above the normal static water level on the leeward side of a body of water caused by wind stresses on the surface of the water.

Piping refers to the internal erosion and carrying away of fine material from within a soil as the result of a flow of water. Refers to the pipe-shaped discharge channel left by erosion which starts at the point of exit of a flow line which exits on the ground surface; typically beneath embankments or on slopes where perched ground water may seep out.

Pockmarked Topography refers to a Karst landscape where the land surface has the general appearance of being scarred and pitted (i.e., surficial depressions).

Reach (shoreline) refers to a stretch of shoreline having similar physiography, geologic composition, average annual recession rate, flooding characteristics and orientation or aspect to waves.

Reach (river and streams) refers to a length of channel over which the channel characteristics are stable or similar. All geomorphological features and types of aquatic habitat should be proportionally represented in the section of the river or stream being assessed, and at least two of each of the major features of the section should be represented.

Retrogressive Failure refers to an unstable slope condition whereby an initial small slip in slope material results in subsequent successive segments of the slope to continue to fail (i.e., slide) in a short period of time.

Shoreline Sediment Compartment refers to a shoreline sediment system which encompasses two littoral cells supplying depositional material to a common sink zone.

Watercourse is flowing water, though not necessarily continuous, within a channel possessing bed and banks that usually discharges into some other stream or body of water.

APPENDIX 1.0
EXAMPLE APPLICATION OF THE SUGGESTED 7 STEP PROCEDURE FOR BALANCING DEVELOPMENT INTERESTS WITH NATURAL HAZARDS: *GREAT LAKES - ST. LAWRENCE RIVER SYSTEM*

This appendix provides an overview of how the Suggested 7 Step Procedure for addressing natural hazards in an environmentally sound manner should be applied. For more detailed information on this procedure, the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996) should be consulted.

i) Step 1: Identify Hazards

The first step involves delineating the *flooding*, *erosion* and *dynamic beach hazards*, with the furthest landward limit of these three hazards defining the *hazardous lands*. Details on mapping and field staking of hazards is provided in the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines (1996)*.

ii) Step 2: Identify Development Proposed Within the *Hazardous Lands* or *Hazardous Sites*

The second step involves identifying the size and nature of the development that is proposed within the *hazardous lands*. The characteristics of the proposed development activity, or the resulting land use, can influence the type of hazard management response to be applied. Except for certain restrictions (i.e., Policy 3.1.3, as discussed in Section 4.2.1), the Policy has the flexibility to permit *development* and *site alterations* to be located within the least hazardous portion of the *hazardous lands*

iii) Step 3: Identify Appropriate Hazard Management Response

Step 3 involves an assessment of how the standards of floodproofing, protection works and access, where they are required or considered to be appropriate, will address the on-site physical hazards.

Table A1: Addressing the Hazards for Development: Initial Evaluation of Shoreline Management Practices provides a summary of all prevention, non-structural and structural protection works options that are considered to be appropriate for application along the shorelines of the *Great Lakes - St. Lawrence River System*. The Table was developed by the Ministry of Natural Resources in consultation with numerous disciplines (e.g., engineering, environmental, coastal geomorphology, etc.; see the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996) for additional information).

In essence Table A1 provides initial guidance on determining whether the proposed shoreline management practice(s) proposed for a given site will or will not address the physical hazard(s). Where portions of Table A1 are left blank, this indicates that the identified management practice is not considered to be the most appropriate given the onshore, backshore and nearshore types.

iv) Step 4: Determine Potential Impacts to Physical Processes and Characteristics

Under Step 4, when considering protection works to address natural hazards, there is the need to assess the impacts of the selected protection works on the area's physical processes and characteristics.

Table A1: Addressing the Hazards for Development: Initial Evaluation of Shoreline Management Approaches by Shoreline Class

Shoreline Class[1]			Typical Hazard(s) • Prone to Flooding • Prone to Erosion • Prone to influence of Dynamic Beach	Appropriate Shoreline Management Approaches for Consideration to Address Flooding, Erosion and Dynamic Beach Hazards at the Site													
				Prevention		Non-structural Protection				Structural Protection (plus stable slope and flood/erosion allowances)							
				Onshore		Onshore				Onshore		Backshore		Nearshore[10]			
General Shoreline Type Onshore/ Backshore (composition and profile)	Controlling Substrate Nearshore (predominant underlying material)	Surficial Substrate Nearshore (can appear along water as a beach)[2]		HA	PA	Re	FP	BM	DE	FI	D	R/S	rR/S	BNT	G	AH	DEI
Bedrock Cliff[3]	bedrock	bedrock	Typically not prone to flooding and erosion hazards (Buffer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)	✓✓✓[11]	✓✓✓	✓✓✓											
		cobble/boulder															
		sand/gravel															
		pillow/gen.[4]															
Bedrock Low Plain[3]	bedrock	bedrock	Prone to flooding. Typically not prone to erosion. (Buffer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)	✓✓✓	✓✓✓	✓✓✓	✓✓			✓✓	✓✓	✓✓	✓✓				
		cobble/boulder															
		sand/gravel															
		pillow/gen.[4]															
Cohesive/Non-cohesive Bluff[5]	bedrock	bedrock	Not prone to flooding. Typically prone to low to moderate erosion. (Buffer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)	✓✓✓	✓✓✓	✓✓✓		✓				✓✓	✓✓	✓~	~✓	✓✓	✓✓
		cobble/boulder												✓~	~✓		
		sand/gravel												✓~	~✓		
		pillow/gen.[4]															
	cohesive cobble/boulder till	cobble/boulder	Not prone to flooding. Typically prone to moderate to high erosion	✓✓✓	✓✓✓	✓✓✓		✓				✓✓	✓	✓~	~✓	✓✓	✓✓
		sand/gravel												✓~	~✓		
		pillow/gen.[4]															
	fine-grained cohesive	cobble/boulder	Not prone to flooding. Typically prone to high to severe erosion	✓✓✓	✓✓✓	✓✓✓		✓				✓				✓	✓
		sand/gravel															
		fine-grained cohesive															
		pillow/gen.[4]															

Table A1 continued on next page

Shoreline Class[1]			Typical Hazard(s) • Prone to Flooding • Prone to Erosion • Prone to Influence of Dynamic Beach	Appropriate Shoreline Management Approaches for Consideration to Address Flooding, Erosion and Dynamic Beach Hazards at the Site													
				Prevention		Non-structural Protection				Structural Protection (plus stable slope and flood/erosion allowances)							
				Onshore		Onshore				Onshore		Backshore		Nearshore[10]			
General Shoreline Type Onshore/ Backshore (composition and profile)	Controlling Substrate Nearshore (predominant underlying material)	Surficial Substrate Nearshore (can appear above water as a beach)[1]		HA	PA	Re	FP	BM	DE	FI	D	fR/S	rR/S	BN†	G	AH	DB‡
Cohesive/Non-cohesive Low Plain3	bedrock	bedrock	Prone to flooding & typically low to moderate erosion (Softer bedrock does erode Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till)	✓✓✓	✓✓✓	✓✓✓	✓↶			✓↶	✓↶	✓✓	✓✓	↶	↶	✓✓	✓✓
		cobble/boulder												↶	↶		
		sand/gravel												↶	↶		
		silt/organic[4]															
	cohesive cobble/boulder till	cobble/boulder	Prone to flooding & typically moderate to high erosion	✓✓✓	✓✓✓	✓✓✓	✓↶			✓↶	✓↶	✓✓	✓	↶	↶	✓✓	✓✓
		sand/gravel												↶	↶		
		silt/organic[4]															
	fine-grained cohesive	cobble/boulder	Prone to flooding & typically high to severe erosion	✓✓✓	✓✓✓	✓✓✓	✓↶			✓↶	✓↶	✓[11]				✓	✓
		sand/gravel															
		fine-grained cohesive															
		silt/organic[4]															
Dynamic Beach Backed by Cliff/Bluff[5]	gravel/cobble/boulder	gravel/cobble/boulder	Prone to flooding, erosion & influence of dynamic beach	✓✓✓	✓✓✓	✓✓✓	✓↶[12]	↶	↶	[12]	[12]	✓✓[12]	✓✓[12]	✓	✓[12]	✓✓[12]	✓✓[12]
	sand	sand		✓✓✓	✓✓✓	✓✓✓	✓↶[12]	↶	↶	[12]	[12]	✓✓[12]	✓✓[12]	✓	✓[12]	✓✓[12]	✓✓[12]
Dynamic Beach Low Plain[6] (mainland dune)	gravel/cobble/boulder	gravel/cobble/boulder	Prone to flooding, erosion & influence of dynamic beach	✓✓✓	✓✓✓	✓✓✓	✓↶[12]		↶	✓[12]	✓[12]	✓✓[12]	✓✓[12]	✓	✓[12]	✓✓[12]	✓✓[12]
	sand	sand		✓✓✓	✓✓✓	✓✓✓	✓↶[12]		↶	✓[12]	✓[12]	✓✓[12]	✓✓[12]	✓	✓[12]	✓✓[12]	✓✓[12]
Dynamic Beach Barrier[7]	gravel/cobble/boulder	gravel/cobble/boulder	Prone to flooding, erosion & influence of dynamic beach	✓✓✓	✓✓✓	✓✓✓	✓↶[12]		↶	[12]	[12]	[12]	[12]	✓	[12]	[12]	[12]
	sand	sand		✓✓✓	✓✓✓	✓✓✓	✓↶[12]		↶	[12]	[12]	[12]	[12]	✓	[12]	[12]	[12]
Artificial			Prone to flooding & erosion	✓✓✓	✓✓✓	✓✓✓	Functional performance and life span of existing structures to be confirmed by engineering study										

See next page for Table A1 legend and notes.

Table A1: Addressing the Hazards for Development: Initial Evaluation of Shoreline Management Approaches by Shoreline Class (continued)

LEGEND AND NOTES

TABLES ARE GENERAL IN NATURE AND ARE ONLY INTENDED TO SERVE AS A GUIDE. THIS TABLE DOES NOT INCLUDE CONSIDERATION OF POTENTIAL UPDRIFT/DOWNDRIFT AND ENVIRONMENTAL IMPACTS. (see Notes)

LEGEND

✓✓✓ - Recommended to address hazards.
✓✓ - Generally will address hazards.
✓ - May be considered but may not provide proper level of protection to address hazard.

→, ← Typically used in conjunction with other structural protection works.

HA - hazard allowances for flooding and erosion
PA - property acquisition
Re - relocation
FP - floodproofing
BM - bluff measures
DE - dune enhancement
FI - filling
D - dyking
BN - beach nourishment
† typically extends across backshore and into nearshore
fR/S - flexible revetments and seawalls
rR/S - rigid revetments and seawalls
G - groynes
AH - artificial headlands (typically with beach fill)
DB - detached breakwater
‡ can also be located in shallow offshore

[1] - This Table does not include classification of shoreline exposure and planform (exposed, partial headland, headland-bay, well sheltered).

[2] - Cliff/bluff - steeper than 1:3 (vert:horz) and >2 m high.

[3] - Low plain - landward slope flatter than 1:3 (vert:horz) or <2 m high.

[4] - Typically only found in naturally well-sheltered areas where controlling substrate may not be applicable.

[5] - A beach is not classified as a *dynamic beach*, where: 1) beach or dune deposits do not exist landward of the stillwater line; 2) beach or dune deposits overlying bedrock or cohesive material are generally less than 0.3 metres in thickness, 10 metres in width and 100 metres in length; or 3) beach or dune deposits are located in embayments, along connecting channels or in other areas of restricted wave action.

[6] - Typically imported cobble/shingle/gravel beach fill with anchoring groynes.

[7] - Very limited structure lifespan.

[8] - Likely insufficient on its own to fully address hazard - must be accompanied by other measures.

[9] - Addresses flood hazard only.

[10] - Nearshore structures require significant analysis and design effort by qualified coastal engineers.

[11] - Technical Guide provides minimum hazard allowance requirements for bedrock.

[12] - Policy does not permit development within *defined portions of dynamic beach hazard*.

NOTES:

Refer to **Table A2**, to assess the potential influences and impacts of shoreline management approaches on the physical shoreline processes and characteristics.

Refer to **Table A3**, to assess the relative significance of the potential impacts with respect to increasing updrift/downdrift flood, erosion and dynamic beach hazards.

Refer to **Table A4**, to assess the biological impacts related to shoreline management approaches.

Tables must be read in conjunction with Technical Guide text.

For the shorelines of the *Great Lakes - St. Lawrence River System,* **Table A2: Summary of Potential Impacts of Shoreline Management Approaches on Physical Shoreline Processes and Characteristics** are described in terms of three key topics:

- **physical shoreline processes and characteristics** (5 main groupings);
- **physical influences** (e.g., changes to the physical processes or characteristics that result from a physical alteration to the shoreline environment); and
- **physical impacts** (e.g., net changes to the physical shoreline environment resulting from the changes in physical processes or characteristics).

By combining all three key topics, Table A2 provides guidance on the range of potential influences and impacts that may result from the installation of a particular form of protection works. These influences and impacts may vary significantly depending on the location (e.g., backshore, onshore, nearshore) and the type of protection work(s) being considered.

For example, within the five main groupings of general physical shoreline processes and characteristics, various forms of shoreline protection works may cause a wide range of "physical influences" which in turn results in different "physical impacts". The range of "**physical influences**" include:

- decreasing the supply of sediments to the littoral zone;
- increasing the supply of sediments to the littoral zone;
- impeding alongshore transport of littoral material;
- impeding cross-shore transport of littoral material;
- diverting littoral sediments from close to shore to deeper water;
- reducing cross-shore transport of littoral materials;
- increasing the reflection of incoming waves;
- concentrating wave action at alongshore ends of protection structures;
- increasing sheltering of nearshore waters;
- occupation of the backshore area;
- reduces wave action at backshore;
- occupation of the nearshore area;
- importing of materials from inland sources are introduced to the shoreline;
- occupation of the onshore area;
- alteration of the onshore terrain (e.g., unstable slope will flatten over time as the crest retreats to stable condition, often these areas are graded to stable slope condition during construction);
- disruption of ground water drainage patterns from the land to the lake/connecting channel, depending on the structure and setting of the site; and
- disruption of surface drainage patterns from the land to the lake/connecting channel.

The range of potential "**physical impacts**" includes:

- increased long-term erosional stress to downdrift shorelines;
- decreased long-term erosional stress to downdrift shorelines;
- accretion updrift and/or in the lee of the structure;
- increased erosion of downdrift shorelines until bypassing occurs;
- increased erosion immediately downdrift;
- less change of the beach and nearshore profile during storms;
- localized erosion (e.g., scour) along the toe and at the alongshore ends of the protection works;
- decreased nearshore wave action;
- decreased mass water exchange and/or circulation of the nearshore waters;
- altered backshore topography at the site;
- altered nearshore topography at the site;
- altered onshore topography at the site; and
- altered surface and/or ground water drainage and/or patterns in the onshore and/or backshore area.

Table A2: Summary of Potential Impacts of Shoreline Management Approaches on Physical Shoreline Processes and Characteristics

General Physical Shoreline Processes and Characteristics	Potential Influences (A._) of Shoreline Management Approaches on Physical Shoreline Processes and Characteristics	Potential Resulting Impacts (B._) on Physical Shoreline Processes and Characteristics	Shoreline Management Approaches													
			Prevention		Non-structural Protection				Structural Protection (plus stable slope & flood/erosion allowances)							
			Onshore		Onshore				Onshore		Backshore		Nearshore			
			HA	PA	Re	FP	BM	DE	FI	D	fR/S	rR/S	BN†	G	AH	DB‡
Supply and Transport of Littoral Materials (Erosion & Deposition Patterns)	A.1 Decreases supply of sediments to the littoral zone	B.1 Increased long-term erosional stress to downdrift shorelines									✓	✓		✓	✓	✓
	A.2 Increases supply of sediments to the littoral zone	B.2 Decreased long-term erosional stress to downdrift shorelines											✓			
	A.3 Impedes alongshore transport of littoral material	B.3 Accretion updrift and/or in lee of structure											✓	✓	✓	✓
		B.4 Increased erosion of downdrift shorelines until bypassing occurs												✓	✓	✓
	A.4 Diverts littoral sediments from close to shore to deeper water	B.5 Increased erosion immediately downdrift												✓	✓	✓
	A.5 Reduces cross-shore transport of littoral material	B.6 Less change of beach and nearshore profile during storms													✓	✓
	A.6 Increases wave reflection from shoreline and increases localized currents	B.7 Localized erosion (scour) along toe of and at alongshore ends of protection works									✓	✓		✓	✓	✓
Water Circulation	A.7 Increases sheltering of nearshore waters	B.8 Decreased nearshore wave action													✓	✓
		B.9 Decreased mass water exchange/ circulation of nearshore waters													✓	✓
Backshore & Nearshore Topography	A.8 Occupies backshore area	B.10 Altered backshore topography at site (changes terrain and materials)									✓	✓	✓	✓		
	A.9 Reduces wave action at backshore	B.10 Altered backshore topography at site (profile becomes more stable)									✓	✓	✓	✓	✓	✓
	A.10 Occupies nearshore area	B.11 Altered nearshore topography (changes bathymetry and materials)									✓	✓	✓	✓	✓	✓
Onshore Topography	A.11 Occupies onshore area	B.12 Altered onshore topography (changes terrain and materials)					✓	✓	✓	✓						
	A.12 Stabilizes toe of cliff/bluff/bank	B.12 Altered onshore topography (with stable toe, crest retreats, as slope flattens to stable condition - often graded during construction)					✓	✓			✓	✓	✓	✓	✓	✓
Surface & Ground Water	A.13 Disrupts surface and/or ground water drainage from land to lake/channel	B.13 Altered surface/ground water drainage pattern in onshore/backshore area					✓		✓	✓	✓	✓				

LEGEND: ✓ - potential impact
HA - hazard allowances
PA - property acquisition
Re - relocation
FP - floodproofing
BM - bluff measures
DE - dune enhancement
FI - filling
D - dyking

fR/S - flexible revetments/seawalls
rR/S - rigid revetments/seawalls
BN - beach nourishment
† in backshore & nearshore
G - groynes
AH - artificial headlands
DB - detached breakwater
‡ can also be located in shallow offshore

NOTES:
This Table is general in nature and applies to many situations in the Great Lakes - St. Lawrence River System. It is intended to serve as a guide in identifying potential impacts. It is not exhaustive and site-specific conditions may differ.

Refer to **Table A1**, for initial evaluation of shoreline management approaches.
Refer to **Table A3**, to assess the relative significance of the potential impacts with respect to increasing updrift/downdrift flood, erosion and dynamic beach hazards.
Refer to **Table A4**, to assess the biological impacts related to shoreline management practices.
Tables must be read in conjunction with Technical Guide text.

The complexity, magnitude and range of influences and impacts associated with any or all of the general physical shoreline processes and characteristics may have a significant impact on the selection, timing and installation of non-structural and structural protection works that may be considered. For more detailed information on the relationship between physical shoreline processes and characteristics and shoreline protection works, consult the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines* (1996).

Determination of the spatial extent of physical impacts are governed by local conditions and processes. The objective is to recognize that physical impacts often extend for significant distances from the development site and as such, should be duly evaluated and recognized in any decision-making process.

In addition to the physical influences and impacts, one should also give **equal consideration** to the potential environmental impacts associated with the various forms of protection works. A detailed discussion of this relationship is examined in Step 6.

v) Step 5: Assess Off-Site Physical Impacts

To aid in the evaluation of potential off-site impacts, **Table A3: Likely Significance of Potential Impacts to Supply and Transport of Littoral Materials with Respect to Increasing Updrift/Downdrift Flooding, Erosion and Dynamic Beach Hazards** was developed (see *MNR Technical Guide for the Great Lakes - St. Lawrence River Shorelines* (1996) for additional information). Table A3 essentially provides an overview of the relative importance of potential physical impacts in terms of their being of **"minor"** or **"major"** in nature.

vi) Step 6: Assess Biological or Environmental Impacts

Step 6 involves a recognition and understanding of the biological or environmental sensitivities and then applying this knowledge in determining the biological impacts associated with various non-structural and structural protection works.

To assist in this evaluation, **Table A4: Significance of Potential Biological/Environmental Impacts** provides an overview and assessment of the significance of potential biological impacts associated with various prevention, non-structural and structural protection works (for more information see the *MNR Technical Guide for Great Lakes - St. Lawrence River Shorelines*, 1996).

Undertaking development in an environmentally sound manner requires that the change to the physical processes associated with protection works be understood and that the effects of these processes on the biological environment be considered and properly addressed.

The location of any protection works (e.g., onshore, backshore, or nearshore) normally dictates to a large degree the biological communities which may potentially be affected. For example, for shoreline areas the range of physical influences and impacts and their associated potential biological impacts which may result from various protection works may result in:

- **increases in long-term erosional stress to downdrift shoreline**
  - may increase the erosion or scouring of the existing shoreline substrate resulting in changes in existing habitat areas (e.g., potential harmful alteration to spawning beds)

- **decreases in long-term erosional stress to downdrift shorelines**
  - may reduce the supply of cobble/gravel or other substrate used for spawning habitat

Table A3: Likely Significance of Potential Impacts to Supply and Transport of Littoral Materials with Respect to Increasing Updrift/Downdrift Flooding, Erosion and Dynamic Beach Hazards

Table A3: Likely Significance of Potential Impacts to Supply and Transport of Littoral Materials with Respect to Increasing Updrift/Downdrift Flooding, Erosion and Dynamic Beach Hazards

Shoreline Class[1]			Significance of Impacts to Supply and Transport of Littoral Materials with Respect to Increasing Updrift/Downdrift Hazards						
General Shoreline Type Onshore/ Backshore (composition and profile)	**Controlling Substrate** Nearshore (predominant underlying material)	**Surficial Substrate** Nearshore (can appear above water as a beach)[5]	**B.1** - Increased long-term erosional stress downdrift	**B.2** - Decreased long-term erosional stress downdrift	**B.3** - Accretion updrift and/or in lee of structure	**B.4** - Increased erosion downdrift until bypassing occurs	**B.5** - Increased erosion immediately downdrift	**B.6** - Less change of beach and nearshore profile[13]	**B.7** - Localized scour at toe and alongshore ends of works
Bedrock Cliff[2]	bedrock	bedrock							
		cobble/boulder							
	(softer bedrock, such as shale, does erode)	sand/gravel							
		silt/organic[4]							
Bedrock Low Plain[3]	bedrock	bedrock							
		cobble/boulder							
	(softer bedrock, such as shale, does erode)	sand/gravel							
		silt/organic[4]							
Cohesive/Non-cohesive Bluff[2]	bedrock	bedrock							
		cobble/boulder	O[11]						O
	(softer bedrock, such as shale, does erode)	sand/gravel	O[11]						
		silt/organic[4]							
	cohesive cobble/boulder till	cobble/boulder	O[11]			O[11]	O[11]		
		sand/gravel	O[11]			O[11]	O[11]		O
		silt/organic[4]							
	fine-grained cohesive	cobble/boulder	O[11]			O[11]	O[11]		
		sand/gravel	O[11]			O[11]	O[11]		
		fine-grained cohesive	O[11]	O[12]	O[12]				O
		silt/organic[4]							

Table A3 continued...(See notes next page)

Table A3: Likely Significance of Potential Impacts to Supply and Transport of Littoral Materials with Respect to Increasing Updrift/Downdrift Flooding, Erosion and Dynamic Beach Hazards

Shoreline Class[1]			Significance of Impacts to Supply and Transport of Littoral Materials with Respect to Increasing Updrift/Downdrift Hazards						
General Shoreline Type Onshore/ Backshore (composition and profile)	**Controlling Substrate** Nearshore (predominant underlying material)	**Surficial Substrate** Nearshore (can appear above water as a beach)[5]	**B.1** - Increased long-term erosional stress downdrift	**B.2** - Decreased long-term erosional stress downdrift	**B.3** - Accretion updrift and/or in lee of structure	**B.4** - Increased erosion downdrift until bypassing occurs	**B.5** - Increased erosion immediately downdrift	**B.6** - Less change of beach and nearshore profile[13]	**B.7** - Localized scour at toe and alongshore ends of works
Cohesive/Non-cohesive Low Plain[3]	bedrock	bedrock							
		cobble/boulder							o
	(softer bedrock, such as shale, does erode)	sand/gravel							
		silt/organic[4]							
	cohesive cobble/boulder till	cobble/boulder				o[11]	o[11]		
		sand/gravel	o[11]			o[11]	o[11]		o
		silt/organic[4]							
	fine-grained cohesive	cobble/boulder				o[11]	o[11]		
		sand/gravel	o[11]			o[11]	o[11]		o
		fine-grained cohesive	o[11]	o[12]	o[12]				
		silt/organic[4]							
Dynamic Beach Backed by Cliff/Bluff[2]	gravel/cobble/boulder	gravel/cobble/boulder	●			●	●		●
	sand	sand	●			●	●		●
Dynamic Beach Low Plain[3] (mainland dune)	gravel/cobble/boulder	gravel/cobble/boulder	●			●	●		●
	sand	sand	●			●	●		●
Dynamic Beach Barrier[5]	gravel/cobble/boulder	gravel/cobble/boulder	●			●	●		●
	sand	sand	●			●	●		●

This Table is general in nature and applies to many situations in the Great Lakes - St. Lawrence River System. It is intended to serve as a guide in identifying potential impacts. It is not exhaustive and site-specific conditions may differ.

LEGEND:

(empty box) **No impact**

o **Minor Impact** - is one which can be mitigated, that is, the proposed structure/activity will cause impacts which can be mitigated through changes in design and/or timing of activity. Confining impacts to what is considered a minor (as opposed to a major) level is contingent upon having an impact of short duration, availability of mitigation practices, a high rate of recovery, and a low potential for spin-off effects. A minor impact can occur when the degree of change in the coastal process is comparatively unimportant or small in magnitude and/or of a localized nature.

● **Major Impact** - occurs when the structure/activity has significant long-term or permanent adverse impacts on the net physical coastal processes on or off site. A major impact can occur when the impact is of long-term duration, the rate of recovery of the coastal process is low, there is a high potential for spin-off or indirect effects and/or the process affected is considered to be a critical process with respect to providing flood and erosion protection. A major impact is notable or conspicuous in effect and scope with respect to increasing the flood, erosion and/or dynamic beach hazard.

NOTES:

- Refer to **Table A1**, for initial evaluation of shoreline management approaches.
- Refer to **Table A2**, to assess the potential influences and impacts of shoreline management approaches on the physical shoreline processes and characteristics.
- Refer to **Table A4**, to assess the biological impacts related to shoreline management approaches.
- Tables must be read in conjunction with Technical Guide text.

1 - This Table does not include classification of shoreline exposure and planform (exposed, partial headland, headland-bay, well sheltered).

2 - Cliff/bluff - steeper than 1:3 (vert:horz) and >2 m high.

3 - Low plain - landward slope flatter than 1:3 (vert:horz) or <2 m high.

4 - Typically only found in naturally well-sheltered areas where controlling substrate may not be applicable.

5 - A beach is not classified as a *dynamic beach*, where: 1) beach or dune deposits do not exist landward of the still water line; 2) beach or dune deposits overlying bedrock or cohesive material are generally less than 0.3 metres in thickness, 10 metres in width and 100 metres in length; or 3) beach or dune deposits are located in embayments, along connecting channels or in other areas of low wave action.

11 - **May result in major impact at downdrift sink (depositional feature such as a beach) or where existing sand/gravel surficial sediments are of sufficient quantity to offset the downcutting of the nearshore profile and a reduction of the existing surficial sediment quantity will increase the downcutting.**

12 - Addition of sand/gravel surficial sediments over a predominantly fine-grained cohesive nearshore profile may increase downcutting.

13 - Impact **B.6** is typically limited to the nearshore area in front of, or lakeward, of the subject site and typically does not extend updrift or downdrift. Hence, it is generally not significant with respect to increasing the updrift/downdrift flood and erosion hazards.

Table A4 Significance of Potential Impacts to the Shoreline Environment

Shoreline Class[1]			Significance of Potential Impacts to the Shoreline Environment													
			Prevention		Non-structural Protection				Structural Protection (plus stable slope and flood/erosion allowances)							
			Onshore		Onshore				Onshore		Backshore		Nearshore			
General Shoreline Type Onshore/ Backshore (composition and profile)	**Controlling Substrate** Nearshore (predominant underlying material)	**Surficial Substrate** Nearshore (can appear above water as a beach)[2]	HA	PA	Re	FP	BM	DE	Fl	D	fR/S	rR/S	BN†	G	AH	DBs
Bedrock Cliff[2]	bedrock	bedrock							t	t	ta	ta	tA	A	A	A
		cobble/boulder							t	t	tA	tA	tA	A	A	A
		sand/gravel							t	t	ta	ta	tA	A	A	A
		silt/organic[4]							tAW	tAW	tAW	tAW	tAW	AW	AW	Aw
Bedrock Low Plain[3]	bedrock	bedrock							t	t	ta	ta	tA	A	A	A
		cobble/boulder							t	t	tA	tA	tA	A	A	A
		sand/gravel							t	t	ta	ta	tA	A	A	A
		silt/organic[4]							tAW	tAW	tAW	tAW	tAW	AW	AW	Aw
Cohesive/ Non-cohesive Bluff[2]	bedrock	bedrock					t		t	t	ta	ta	tA	A	A	A
		cobble/boulder					t		t	t	tA	tA	tA	A	A	A
		sand/gravel					t		t	t	ta	ta	tA	A	A	A
		silt/organic[4]					t		tAW	tAW	tAW	tAW	tAW	AW	AW	Aw
	cobble/boulder till	cobble/boulder					t		t	t	tA	tA	tA	A	A	A
		sand/gravel					t		t	t	ta	ta	tA	A	A	A
		silt/organic[4]					t		tAW	tAW	tAW	tAW	tAW	AW	AW	Aw
	fine-grained cohesive	cobble/boulder					t		t	t	tA	tA	tA	A	A	A
		sand/gravel					t		t	t	ta	ta	tA	A	A	A
		fine-grained cohesive					t		t	t	ta	ta	ta	A	A	A
		silt/organic[4]					t		tAW	tAW	tAW	tAW	tAW	AW	AW	Aw
Cohesive/ Non-cohesive Low Plain[3]	bedrock	bedrock							t	t	ta	ta	tA	A	A	A
		cobble/boulder							t	t	tA	tA	tA	A	A	A
		sand/gravel							t	t	ta	ta	tA	A	A	A
		silt/organic[4]							tAW	tAW	tAW	tAW	tAW	AW	AW	Aw

continued...

Shoreline Class[1]			Significance of Potential Impacts to the Shoreline Environment													
General Shoreline Type Onshore/ Backshore (composition and profile)	Controlling Substrate Nearshore (predominant underlying material)	Surficial Substrate Nearshore (can appear above water as a beach)[5]	Prevention		Non-structural Protection				Structural Protection (plus stable slope and flood/erosion allowances)							
			Onshore		Onshore				Onshore		Backshore		Nearshore			
			HA	PA	Re	FP	BM	DE	Fl	D	fR/S	rR/S	BN†	G	AH	DB‡
Cohesive/ Non-cohesive Low Plain[3] (continued)	cobble/boulder till	cobble/boulder							t	t	tA	tA	tA	A	A	A
		sand/gravel							t	t	ta	ta	tA	A	A	A
		silt/organic[4]							tAW	tAW	tAW	tAW	tAW	AW	AW	Aw
	fine-grained cohesive	cobble/boulder							t	t	tA	tA	tA	A	A	A
		sand/gravel							t	t	ta	ta	tA	A	A	A
		fine-grained cohesive							t	t	ta	ta	ta	A	A	A
		silt/organic[4]							tAW	tAW	tAW	tAW	tAW	AW	AW	Aw
Dynamic Beach Backed by Cliff/Bluff[2]	gravel/cobble/boulder	gravel/cobble/boulder					T		T	T	TA	TA	TA	A	A	A
	sand	sand					T		T	T	Ta	Ta	Ta	A	A	A
Dynamic Beach Low Plain[3] (mainland dune)	gravel/cobble/boulder	gravel/cobble/boulder							T	T	TA	TA	TA	A	A	A
	sand	sand							T	T	Ta	Ta	Ta	A	A	A
Dynamic Beach Barrier[5]	gravel/cobble/boulder	gravel/cobble/boulder							T	T	TA	TA	TA	A	A	A
	sand	sand							T	T	Ta	Ta	Ta	A	A	A
Artificial							Should be evaluated on a site specific basis									

LEGEND:

T - major impact on terrestrial habitats
t - minor impact on terrestrial habitats
A - major impact on aquatic habitats
a - minor impact on aquatic habitats
W - major impact on wetlands

HA - hazard allowances for flooding and erosion
PA - property acquisition
Re - relocation
FP - floodproofing
BM - bluff measures
DE - dune enhancement
Fl - filling
D - dyking

fR/S - flexible revetments and seawalls
rR/S - rigid revetments and seawalls
G - groynes
AH - artificial headlands (typically with beach fill)
DB - detached breakwater
‡ can also be located in shallow offshore
BN - beach nourishment
† typically extends across backshore and into nearshore

1 - This Table does not include classification of shoreline exposure and planform (exposed, partial headland, headland-bay, well sheltered).
2 - Cliff/bluff - steeper than 1:3 (vert:horz) and >2 m high.
3 - Low plain - landward slope flatter than 1:3 (vert:horz) or <2 m high.
4 - Typically only found in naturally well-sheltered areas where controlling substrate may not be applicable.
5 - a beach is not classified as a *dynamic beach*, where: 1) beach or dune deposits do not exist landward of the still water line; 2) beach or dune deposits overlying bedrock or cohesive material are generally less than 0.3 metres in thickness, 10 metres in width and 100 metres in length; or 3) beach or dune deposits are located in embayments, along connecting channels or in other areas of restricted wave action.

NOTES:

Refer to **Table A1**, for initial evaluation of shoreline management approaches.

Refer to **Table A2**, to assess the potential influences and impacts of shoreline management practices on the physical shoreline processes and characteristics.

Refer to **Table A3**, to assess the relative significance of the potential impacts with respect to increasing updrift/downdrift flood, erosion and dynamic beach hazards.

Refer to additional Tables in Technical Guide to assess the biological impacts related to shoreline management practices.

Tables to be read in conjunction with Technical Guide text.

- **accretion updrift and/or in the lee of the structure**
  - may cover the existing substrate (e.g., cobble) with finer sediments
- **increases in erosion on immediately downdrift shorelines**
  - alteration to aquatic vegetation patterns
- **less adjustment of the dynamic beach profile during storms**
- **induces localized erosion or scour along the toe and at the alongshore ends of the protection works**
  - increases deposition of fine materials on existing substrates
- **alteration to the topography on-site**
  - clearing of vegetation may disturb wildlife habitat by removing protection, cover and food sources for various species
  - increases in suspended sediment due to increased surface runoff and erosion
- **alteration to the nearshore topography**
  - aquatic habitat is altered
  - increase of suspended sediments during construction
  - change in topography may alter the amount of light reaching the lake bottom
  - covering and/or loss of spawning substrate for certain fish species, possibly resulting in a change from one habitat type to another
  - replacement and/or removal of cover such as boulders, sunken logs, etc
  - removal of aquatic vegetation
  - may bury or limit the productivity of benthic invertebrates
  - may alter the shallow wave zone
- **alteration to the onshore topography**
  - removal of existing vegetation
  - soil compaction and increased erosion
- **alteration to the surface and/or ground water drainage patterns in the backshore and/or onshore**
  - increased sedimentation from the excavated surface drainage channel
  - disruption of migration and/or spawning activity of fish dependent on small streams
  - change to drainage

Based on an assessment of each of the critical factors, namely ecosystem susceptibility to disturbance, the potential effects on the biological and physical environment, and the level of impact (i.e., major/minor) a determination on the environmental soundness of a particular development proposal can be made.

vii) Step 7: Mitigate Minor Impacts of Preferred Hazard Management Response

The proposed *development* and *site alteration* may proceed where all of the matters outlined in Policies 3.1.2 and 3.1.3 are fulfilled, as outlined in Steps 1 through 6, and any minor impacts are mitigated by alterations to the design and/or to the timing and method of installation.